SEG TDR 64-29

A STUDY OF EXISTING BASE FUEL HANDLING PROCEDURES IN RELATION TO MICROBIAL CONTAMINATION

TECHNICAL DOCUMENTARY REPORT No. SEG TDR 64-29

JUNE 1964

SYSTEMS ENGINEERING GROUP
RESEARCH AND TECHNOLOGY DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Project No. 8169, Task No. 816906

(Prepared under Contract No. AF 33(657)-9762 by Southwest Research Institute, San Antonio, Texas; Robert K. Johnston, F. W. Bieberdorf, R. G. Weichlein, J. C. Tyler and R. D. Brown, Authors)

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Qualified requesters may obtain copies of this report from the Defense Documentation Center (DDC), (formerly ASTIA), Cameron Station, Bldg. 5, 5010 Duke Street, Alexandria, Virginia, 22314.

This report has been released to the Office of Technical Services, U.S. Department of Commerce, Washington 25, D. C., in stock quantities for sale to the general public.

Copies of this report should not be returned to the Research and Technology Division, Wright-Patterson Air Force Base, Ohio, unless return is required by security considerations, contractual obligations, or notice on a specific document.

200 - July 1964 - 162-47-960

FOREWORD

This report was prepared at Southwest Research Institute under USAF Contract AF 33(657)-9762. The contract was initiated under Project No. 8169, Task No. 816906. The work was administered by the Systems Engineering Group, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. The project engineer was Mr. K. F. Stevenson, SEHFL.

This report covers work performed from 24 September 1962 through 8 April 1964.

The authors wish to acknowledge the contributions of Mr. J. K. Dean and Mr. R. S. Jenkins in obtaining the experimental data presented in this report. The authors also wish to acknowledge the considerable assistance provided by the following individuals in connection with the survey and sampling program:

Lt. James M. Pope III, Fuels Supply Officer, Bergstrom AFB, Texas

Lt. Sanford A. Richardson, Fuels Supply Officer, Carswell AFB, Texas

Mr. Joe W. Phillips, Acting Base Petroleum Officer, Kelly AFB, Texas

ABSTRACT

A survey of the JP-4 fuel handling facilities and procedures at three Air Force bases has indicated no serious contamination, microbial or otherwise. The water bottoms throughout the fuel systems were either sterile or contained very few microorganisms, with appreciable counts observed only on a single sample from each base. The general housekeeping and observance of prescribed fuel handling procedures appeared adequate.

Experimental studies were made of microbial growth in 4000-gallon tanks and in 15-gallon drums, in which JP-4 fuel was stored over dilute sea water with varying proportions of glycerin and methoxyethanol, inoculated with selected microorganisms. Effective inhibition of growth was observed in water bottoms containing 20% methoxyethanol, and some inhibition with 10% methoxyethanol; lower concentrations allowed vigorous growth. It was found that the addition of 20% methoxyethanol effectively sterilized the contents of a tank in which growth was already established.

A review was made of the pertinent journal and report literature and also of the Air Force technical orders and manuals in this field. Certain contradictions, omissions, and shortcomings were observed in the Air Force documents. Based on this review and on the survey and sampling programs, certain recommendations for fuel handling procedures have been drawn up in technical order (T.O.) format.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF TABLES (Cont'd)

I. INTRODUCTION

The contamination of jet fuels by microbial growth, water, rust, and other solid contaminants has led to a number of operational problems, including aircraft fuel tank corrosion, fouling of instrument probes, and blockage of filter screens in the aircraft fuel system. Among the various techniques that are being investigated for mitigation of these problems, the most direct and and obvious approach is elimination of the water and solid contaminants that furnish the favorable environment for microbial growth. Complete elimination of such contaminants in a large-scale fuel handling system may be unattainable for economic reasons; however, it should be possible to effect a drastic reduction in contamination level, without any major changes in facilities or equipment, by optimizing the fuel handling procedures and control criteria.

The program reported herein was directed toward a study of existing Air Force base fuel handling procedures, equipment, and control criteria, in order to pinpoint areas where improvement is needed and to develop recommendations for improved procedures or control criteria. The program included a survey of operations at three Air Force bases, an experimental program on microbial growth in JP-4 fuel stored in tanks and drums, a thorough review of the Air Force documentary literature on fuel facilities and fuel handling, a survey of the highlights in the report and journal literature, and the development of recommendations for improved fuel handling procedures and control criteria.

This program is part of an extensive effort by the Air Force and other governmental and industrial organizations to study and attempt to mitigate the severe problems in corrosion and fouling that have been associated with microbial growth. These problems are being attacked on a broad front ranging from basic studies of microbial growth and metabolism to engineering studies such as the program reported herein. Between these extremes, major programs are under way in developing new tank coatings, investigating the use of microbiocides and nonchemical kill or control techniques, and studying the factors influencing tank corrosion.

Since the history of the use of additives in JP-4 fuel is quite pertinent to contamination problems, it will be reviewed briefly. The classes of additives involved are antioxidants, metal deactivators, corrosion inhibitors, and anti-icing additive. Of these types, the antioxidants and metal deactivators apparently have little effect on microbial growth, other than furnishing additional sources of nutrient in some cases.

Manuscript released by authors 8 April 1964 for publication as an RTD Technical Documentary Report.

Corrosion inhibitors were first approved for use in JP-4 in late 1957. Some of these inhibitors had extremely adverse effects on the water-separating and filterability properties of JP-4. This was not generally recognized at first, since there was no adequate laboratory test for this property. The severity of the problems led to almost complete suspension of the use of corrosion inhibitors while the CRC water separometer test was being developed and evaluated. At the same time, backup data were being obtained in full-scale and single-element filter-separator units. This work resulted in the incorporation of the CRC water separometer in the JP-4 specification and the reinstatement of the mandatory use of corrosion inhibitors in JP-4 fuel, as of 1 April 1963. It should be pointed out that all of the Air Force base survey work reported herein was performed during the period in which no corrosion inhibitor was allowed in JP-4 fuel.

The other JP-4 additive that is of major importance in fuel handling operations is the anti-icing additive, which was added in 0.1% concentration to all JP-4 starting 1 April 1962. This additive originally consisted of 90% methoxyethanol* and 10% glycerin (by volume); the glycerin was used to prevent damage to aircraft fuel tank topcoatings by the methoxyethanol that accumulates in the aqueous phase. This formulation gave rather severe difficulties with "fallout" of the glycerin component throughout fuel handling systems, including refiners' blending tanks and trucks, base storage tanks, filter-separators, aircraft tanks, etc. Evidently the glycerin content of the blend was too high to remain in solution when small amounts of water were picked up by the fuel. The glycerin content of the additive was reduced to 2% in the fall of 1962, and more recently to 0.4%. During the survey reported herein, the glycerin content of the additive being supplied was 2%, but possibly residues remained from the older 10% glycerin material in some tank bottoms.

In view of the major effects of the anti-icing additive on microbial growth, as reported in numerous laboratory and field studies, the experimental portion of the program reported herein was aimed at studying these effects under conditions of storage in tanks and drums.

Concurrent with the field survey and experimental program, a thorough review was made of the Air Force documentary literature (regulations, technical orders, and manuals) on fuel handling facilities and procedures. The findings in this review and in the field survey were used to draw up recommended practices that are incorporated herein as Appendix B. In addition, the pertinent report and journal literature was reviewed, and selected items incorporated in a bibliography in this report.

*More correctly, 2-methoxyethanol, also known as monomethyl ether of ethylene glycol.

II. SUMMARY AND CONCLUSIONS

A. Survey of Existing Facilities and Operations

As described in Section III, surveys at Bergstrom and Carswell AFB have indicated that general housekeeping in the fuel handling system at these bases was quite good and that no serious contamination problems existed, microbial or otherwise. The incoming fuel, which was received by tank car or tank truck, was of good quality both as to contamination level and water separation index. The practice of making a visual check on fuel from each incoming shipment was observed at Carswell but did not appear to be followed at Bergstrom. Neither base made any regular check on bottom or drain samples.

The bulk storage capacity at these bases was apparently insufficient to permit scheduling four-hour settling in all cases prior to dispensing fuel to hydrant systems. Each base had two 13,000- to 20,000-bbl floating-roof storage tanks, and Carswell also had four 4,500-bbl fixed-roof tanks. All tanks had fixed lines for receiving and issuing fuel, located about one foot off the bottom. So far as could be determined, none of the tanks had a true low-point sump for draining water. The normal water bottom in the floating-roof tanks, as determined by gaging, was from one to two inches. At Carswell, data on the daily water gage of the tanks were compared with daily precipitation data, indicating that access of rain water through the floating-roof seal was a primary source of the introduction of water to these tanks.

The water bottoms in the floating-roof tanks were almost completely free of viable microorganisms at both bases. The highest counts observed on any of the floating-roof tank water bottoms and interfacial material were not more than 30/ml, and many of the samples were entirely sterile. The Carswell fixed-roof tanks were used for reserve storage and were often stagnant for 30 or 40 days at a time. Only one of these tanks contained recoverable water; the bacterial count on this water was 2470/ml. This count, although one of the highest encountered in the survey, is still so low as to indicate no problem with microbial contamination.

The methoxyethanol content of the water bottoms from the floating-roof tanks was about 20% at Bergstrom and 33% at Carswell. These concentrations are fairly well in line with the equilibrium methoxyethanol content of water that is in contact with fuel containing 0.1% methoxyethanol, at the winter temperatures prevailing at these two bases. The glycerin contents of the water bottoms were

3% or less in all cases. In contrast, tank bottom samples from Kelly AFB a few months previously had shown up to 70% of glycerin, probably representing residues from the 10% glycerin additive formerly used.

The bulk storage and receiving area at Carswell AFB included a truck fill stand supplied directly from bulk storage tanks or from incoming tank cars or tank trucks, without any intervening filter-separator. The cleanliness of the fuel at this fill stand was surprisingly good, based on a single sample.

The underground operating storage tanks at Bergstrom and Carswell were similar to the bulk storage tanks with respect to composition of the water bottoms and freedom from microbial contamination. These tanks contained very little water, at least at the gaging and sampling points, and it was indicated that it is seldom necessary to pump any water from them. This could mean that very little water is entering, or it could mean that the water is kept stirred up and pumped out along the fuel. The presence of free water in one Bergstrom tank sample taken several feet off the bottom, three hours after receiving defuel, would support the pessimistic view. Examination of samples from Carswell operating storage tanks showed excessive solids contents in the fuel from every tank in one operating storage area.

The differential pressure gages installed on fixed filter-separators have given extremely poor service at Bergstrom, while Carswell's experience (with a different make of gage) has been very good. Bergstrom tended to ignore the readings, since their gages were so unreliable.

Only a few samples were drawn from refueling operations at Bergstrom and none at Carswell, owing to security restrictions. The Bergstrom samples indicated adequate cleanliness. The drawing of sump drain samples for laboratory analysis seemed to be quite a problem at both bases, especially at Carswell, where fuel supply personnel were not allowed to handle this operation.

Considerable confusion existed on the criteria for changing elements in filter-separators in operating storage areas and on vehicles and hose carts. Bergstrom was applying a pressure differential criterion of 8 psi to all fixed filter-separators, in spite of nameplate data on some of their units calling for change at 3.5 psi. This is of only academic interest, however, so long as the differential pressure gages were not functioning properly. At Carswell, filter-separator elements on the MV-2 hose cart were apparently never changed on the basis of time or gallonage, and there is nothing in the applicable T.O. to say that they are wrong in this interpretation. It was also indicated that they might backwash the elements on these units if differential pressure built up to the allowable limit.

Sump drain samples taken at Bergstrom and Carswell indicated moderate amounts of water and solid contaminants, but nothing that would indicate any problem with microbial contamination. The B-52's seemed to show the most water in the sump drains, especially those from the outboard tanks. The highest bacterial counts, on the order of a few thousand per milliliter were found in the B-52 sump drain sample from Bergstrom. Bergstrom's KC-135's were quite clean by comparison. Samples from a B-58 at Carswell showed a fair amount of assorted chunks of material and fine particles in the drain sample from the reservoir tank, and lesser amounts from the other tanks.

Laboratory experience at both Bergstrom and Carswell indicated that the Millipore solids determinations on fuel effluents from filter systems were of considerable value in detecting malfunctions. There was also agreement that the Karl Fischer water determinations were of little value.

B. Experimental Program

As described in detail in Sections IV and V, storage tests were conducted in 4000-gallon tanks and in 15-gallon drums, in which JP-4 fuel was stored over a water bottoms consisting of dilute sea water with varying proportions of glycerin and methoxyethanol, inoculated with raw cultures from Bergstrom AFB bulk storage and selected pure cultures of bacteria and fungi. The use of 20% methoxyethanol in the water bottoms gave effective inhibition of growth in four-month tests on drum samples. 10% methoxyethanol gave some inhibition, and 0-2% methoxyethanol allowed vigorous growth. Similarly, in 4000-gallon underground tanks, the addition of 20% methoxyethanol to the dilute sea water bottoms was effective in sterilizing growth that had already been established.

The pH values of the water bottoms decreased to 4.0-5.4 in the drum tests and to 5.0-5.6 in the tank tests. There was no clear-cut correlation of the pH values with either composition of the water bottoms or with the extent of microbial growth.

The presence of bare steel, bare aluminum, and coated steel (MIL-C-4556) specimens in the drum tests had a definite accelerating effect on microbial growth, as compared to parallel tests with bare steel specimens only.

Sulfate-reducing bacteria were found in the underground tank that was not treated with methoxyethanol, but not in the treated tank nor in any of the drum storage tests. It is probable that these were extraneous microorganisms, as the underground tanks were not sterilized before setting up the tests.

Other than sulfate reducers, the following were detected in the untreated tank: Pseudomonas aeruginosa, Proteus sp., facultative anaerobes, some

coliform types, and iron depositors. Microorganisms detected in the drum storage tests included Staphlyococcus aureus, iron depositors, facultative anaerobes, gas-formers, coliforms, and the following fungi genera: Aspergillus, Hormodendrum, Penicillium, Fusarium, Paecilomyces, and Alternaria.

The program of microbiological sampling and analysis demonstrated rather graphically the virtual impossibility of obtaining truly representative samples from large storage containers. Each sample represents one point in space and time, which cannot be duplicated in subsequent sampling. It is thought that clumping of microorganisms also contributed to difficulty in the dilution and counting procedures. In any event, a microbiological assay of a storage tank sample represents, at best, order-of-magnitude validity.

The results of studies of stir-up phenomena in the underground storage tanks were largely inconclusive, as the contamination level was inadequate. It appears that long-term service, as well as the passage of large quantities of fuel, is necessary to approach the tank contamination levels commonly observed in Air Force base fuel storage.

In view of the demonstrated effectiveness of the methoxyethanol in suppressing microbial growth, it is suggested that regular analysis should be made for the methoxyethanol content of water bottoms in Air Force base tank bottoms and aircraft sumps. Such information would be of a considerable value in controlling microbial growth problems, as well as in giving a better picture of the antifreeze properties of the additive in practice.

C. Review of Air Force Documents on Fuel Handling

A review of the T.O.'s and manuals pertaining to fuel handling has revealed a number of contradictions and some omissions. The most important of these are summarized in the following paragraphs, and a more extensive discussion is given in Section VI.

No specific instructions were found governing the installation of low-point sumps in bulk storage tanks. It appears that this should be made mandatory whenever a bulk storage tank is opened up for inspection. Similarly, there is no indication in the T.O. literature that underground tanks should be installed with a pitch toward one end, to assure that water can be removed completely. The regulations on the frequency of tank cleaning are somewhat confusing, and should be clarified. This same comment applies to the existing instructions on settling time required.

There are numerous contradictions in the T.O.'s and manuals on the proper method of sampling incoming tank cars and tank trucks and on the checking and cleaning of strainers in the fill plugs and unloading line. It appears desirable to set up some standard method of checking the bottoms of incoming tank cars and tank trucks; at present, such checks are not mandatory.

Some of the most serious confusion in the T.O. literature pertains to the criteria for changing filter-separator elements. The basic T.O. usually cited for fixed filter-separators, T.O. 37A9-1-506, refers (strictly speaking) to old "hay-pack" units that have been converted to filter-separators. Further, this T.O. calls for a gallonage requirement that is impractical to apply in the absence of meters. The criteria for mobile filter-separators are in somewhat better shape, since in most cases they are covered by T.O.'s applicable to the individual refueler or hose cart. However, in the case of the MV-2 hose cart there is nothing in the T.O.'s to indicate any time or gallonage requirements for element change. Although the T.O. says that gallonage and time requirements should be "in accordance with established U. S. Air Force procedures," there does not seem to be any established procedure that covers mobile filter-separators in general.

There is very little information pertaining to the scheduling of hydrant operations. A three-hour settling period in the operating storage tanks after transferring from bulk storage tanks is suggested "if conditions permit." It is evident that operating schedules at some bases will not permit much (if any) settling time. Under these conditions, the operating storage tank is not acting as a site for the removal of contaminants, but simply an additional source of contaminants. It is recommended that serious consideration should be given to the concept of a "clean" operating storage system. Such a change in philosophy would involve major modifications of facilities and procedures, but could lead to significant reduction of the load on the fixed and mobile filter-separators.

Another subject that is given very little attention in the T.O.'s is quality control of defuel. In fact, the approach is rather negative, in that there is no requirement for even checking the fuel unless it is for some reason suspected of being contaminated. It appears that some definite requirement for visual checks should be instituted. This is particularly important in the case of Panero-system hydrant defueling, where the defuel passes directly into the operating storage tanks without any filtering whatever.

Regarding the frequency of sampling, the existing T.O.'s and manuals seem to require only yearly sampling of fuel in bulk storage tanks. It is suggested that at least weekly checks would be desirable, to give some indication of whether settling periods and inlet line configuration are such that no gross contamination is present in the fuel. Improved methods of tank sampling are

needed, since presently available samplers are not suitable for obtaining samples at accurately determined depths.

The existing T.O.'s do not require any sampling of effluents from fixed filter-separators, as the "filter system" for sampling purposes is interpreted to mean the last-chance filter or filter-separator. It is believed that regular sampling of the fixed filter-separator effluents for visual examination would be of value in detecting malfunctions. The "last-chance" samples are now taken, if possible, from a sampling cock installed in the refueling nozzle. It is suggested that the taking of full-flow samples, from sampling cocks either on the nozzle or on the filter-separator outlet, should be made mandatory.

Criteria for visual examination of refueling samples have been stated in a SAC manual and in one T.O. It appears that visual examination could be made considerably more valuable if the shape of the sample bottle and the viewing conditions could be standardized. Also, it would appear that visual examination should be required on every refueling operation. Some bases may observe this practice, but it is not mandatory in the T.O.'s and manuals. It would also be desirable, somewhere in this literature, to discuss sample bottle cleaning in some detail.

The question of aircraft sump drain samples seems to have generated a great deal of confusion, since both the fuel supply group and aircraft servicing personnel are involved. It is felt that some improvement is needed here, so that fuel laboratory personnel are more cognizant of what these samples represent. The requirement for laboratory analysis of sump drain samples exists only in SACM 67-2, and this merely specifies that they shall be taken. Some better definition of how these samples are taken and of the responsibilities of the two groups seems to be needed.

The analysis of fuel samples for solids and water content, as instituted at SAC bases a year or two ago, has created some real problems in workload and in obtaining qualified laboratory personnel. The Millipore solids determination seems to be of considerable value, and it is believed that its use should be continued and extended. The Karl Fischer water determination as described in the applicable T.O. is subject to serious questions in interpretation of the results in terms of water saturation limit. Certain possible improvements in this method and interpretation are described in the text of this report (Section VI).

D. Recommended Fuel Handling Practices

Based on the survey and sampling programs and on reviewing the existing documents, certain recommendations for fuel handling practices have been drawn up. These are discussed in Section VII and given in the form of a Technical Order (T.O.) in Appendix B.

E. Review of Report and Open Literature

A selective review of the journal and report literature pertaining to fuel contamination is presented in Section VIII, and a bibliography in Section IX.

III. REVIEW OF FUEL HANDLING OPERATIONS AT BERGSTROM, CARSWELL, AND KELLY AIR FORCE BASES

A. General

This section contains a description of the fuel handling facilities and operations at three Air Force bases in Texas. Two SAC bases (Bergstrom and Carswell) were visited by a three-man team for a one-week survey and sampling program at each base, with some follow-up visits. Kelly AFB was visited intermittently, without any organized survey or sampling program.

The information contained in this section was obtained by direct observation and by discussions with personnel from fuels supply, civil engineering maintenance, and aircraft servicing groups. Security limitations prevented free access to the flight line to observe refueling or sump draining procedures or to draw samples.

The sampling programs were aimed at obtaining a representative selection of fuels and water bottoms from all points in the system, including incoming shipments, bulk storage, operating storage, refueling operations, and aircraft sump drains. The samples were taken in cleaned glass bottles, which were also sterilized for the microbiological sampling. However, it should be pointed out that sampling was not conducted under aseptic conditions in all cases, since it was often necessary to use intermediate nonsterile containers, funnels, or sampling devices. Also, samples were brought back to the SwRI laboratories in San Antonio for microbiological assays and chemical and physical tests. Although the samples were held in cold storage from the time of sampling until the microbiological cultures were made (a period of one week or less), it is recognized that the microbial populations may have changed significantly within this time. However, it is believed that the data obtained do serve to establish general levels of contamination through the system in relation to fuel handling facilities and procedures.

In addition to the microbiological assays, determinations were made of the solids content of selected fuel samples and the chloride, glycerin, and methoxyethanol content of selected samples of water bottoms.

Visual observations at the time of sampling were not found too reliable in correlating with fuel quality, owing to the combination of diverse viewing conditions and different observers. All samples were observed some time later with side lighting and black background, both in the "as settled" condition and also after shaking; these are the observations reported herein. A

word should be said about the terms used in describing the number of particles in fuel samples. In general, "few" refers to 5-25 particles, and "many" or "numerous" refers to possibly 25-100 or 150 particles. No actual counts were made. The terms "small amount," "fair amount," "considerable," etc., refer to increasingly larger numbers of particles, all well above the range of visual estimation of the number.

B. Bergstrom AFB

1. General

All of the information on Bergstrom was obtained in early 1963, and it should be recognized that changes in facilities and/or operations may well have occurred since that time.

At the time of the survey, the principal operating aircraft were B-52D's and KC-135's.

Fueling operations apparently continued around the clock, tapering off between 0300 and 0700. Fuel was usually transferred from bulk storage to operating storage at night, since during the day the transfer pumps were normally tied up in unloading incoming tank trucks.

It appeared that very little fuel from other bases entered the Bergstrom system via defueling operations, as it was indicated that with few exceptions the Bergstrom planes were fueled with JP-4 from Bergstrom. The amount of transient aircraft operation at Bergstrom was said to be negligible, and presumably there would not be any defueling of such aircraft under ordinary circumstances.

2. Fuel Supplies

a. General

Bergstrom was using about 120,000 gal/day of JP-4. The suppliers at the time of the survey, for the contract period from 1 October 1962 through 31 March 1963, were as follows:

Supplier	Contract Amount, Million Gallons	Method of Delivery
Humble Oil and Refining Co., Baytown, Texas (refinery)	9.75	Pipeline from Baytown to bulk terminal in Austin; then to Bergstrom by tank truck (Robinson Truck Lines)
Howell Refining Co., San Antonio, Texas (refinery)	3.00	Tank truck from San Antonio, Texas
Danaho Refining Co., Pettus, Texas (refinery)	6.00	Tank truck from Pettus, Texas
Cardinal	3.00	Tank truck from Pettus, Texas (presumably Danaho fuel) and from Corpus Christi, Texas (source unknown)
International Marketing		Very small amount; not delivering

All JP-4 was being brought in by truck, during daylight hours. For the next contract period, Bergstrom had planned to get a major portion of their fuel by pipeline, since a short connection to the base had just been completed, filled with fuel, and tested. However, the awards for the next period (April-September 1963) included only the following (millions of gallons)

Howell	4
Danaho	4
Monarch	1
Cardinal	2.25
GATX	0.36

None of these bids were on the basis of pipeline delivery. Since the total of these awards was only about one-half of Bergstrom's six-month requirements, it is evident that supplementary procurements would be made during this period. The current status of fuel supplies has not been ascertained.

Bergstrom personnel stated that they had not encountered any trouble with "fallout" of the glycerin component of the anti-icing additive

except in the case of one supplier, and that several loads of fuel from this supplier had been rejected for this reason. Some of this trouble was blamed on dirty truck tanks. Bergstrom maintenance personnel mentioned troubles with filter-screen plugging during the unloading of this supplier's trucks during that period of general difficulty. The glycerin fallout problem was quite widespread at the time the anti-icing additive with high glycerin content was in use.

Details on fuel sources, additives, and blending and handling procedures were obtained from three of the suppliers, as discussed in the following paragraphs.

b. Humble Oil and Refining Company

JP-4 was being supplied from the Humble Baytown refinery via pipeline to Humble's Austin bulk terminal, from which it was trucked to Bergstrom. At the time of the survey, the JP-4 did not contain any corrosion inhibitor other than what it might pick up in the pipeline.

The Humble JP-4 consisted of straight-run kerosine and a light naphtha, with some butane added if necessary to increase vapor pressure. The kerosine was cut from sweet and Coastal crudes, caustic washed and then sweetened if necessary to meet doctor and mercaptan specifications. The napththa was derived as the raffinate in sulfur dioxide extraction of xylene from the Baytown hydroformer product.

The Austin terminal had one 32,000-bbl floating-roof tank in JP-4 service. At the time of the survey the fuel was received directly into this tank without any filtration, at least at the Austin terminal. Their new pipeline receiving setup included a water separator, a Warner-Lewis HPD-5457 filter (PL conversion), and a Rotovac 8-inch A-24-950 "self-cleaning" filter. It was planned to receive jet fuel through this setup.

The anti-icing additive was injected into the fuel as it entered the tank, using tank circulation and injection of extra additive if their analysis showed the need.

The floating-roof tank was equipped with a flexible-hose internal roof drain. The foot valve of this drain was normally kept open, because of some experience at another Humble terminal with roof damage during heavy rains. The JP-4 tank at the Austin terminal was equipped with floating suction. The tank bottom was sloped 3" down toward the center, with a sump in the center and a water drain line extending down into the sump. It was said that water was drained off after each rain, and that the water bottoms had been quite dark at times. Apparently there was no regular schedule for

tank cleaning, and it was pointed out that one of the other tanks had not been inspected for some twelve years.

The truck loading stand at this terminal included a 1000-gpm filter-separator, Warner-Lewis VFCS-2461-15A3C, with CS-51 coalescers and CEA-3 separators.

c. Howell Refining Company

The Howell JP-4 consisted of straight-run naphtha and kerosine cuts from gas-well retrograde condensate, with minor amounts of a purchased blend stock. No treatment of any kind was required to meet specifications. The base fuel components were accumulated and blended in a cone-roof tank. When loading trucks from this tank, the fuel was pumped upflow through a 4000-gallon column containing rock salt and then to the truck loading rack. Anti-icing additive was injected into the line between the salt tower and the loading rack. As of December 1962, they had converted over to the 2% glycerin anti-icing additive. No other additives were used in their fuel.

d. Danaho Refining Company

The Danaho JP-4 was similar to the Howell in source, treatment, and additives. The Danaho blend stocks were said to pass through a calcium chloride tower on their way from the still to storage and blending tanks. The anti-icing additive was injected into this line directly after the calcium chloride tower. They had changed over to the 2% glycerin anti-icing additive in November 1962. They reported no troubles with loss of anti-icing additive or with dark-colored tank bottoms.

3. Bergstrom Facilities and Procedures

a. General

Bergstrom's bulk storage, two floating-roof tanks, was receiving JP-4 by tank truck only at the time of the survey, although tank car unloading facilities were available and a pipeline connection had just been completed. The bulk storage area included an unloading stand for ten trucks, transfer pumps, and a filter-separator and truck fill stand.

The operating storage included one Panero pumphouse and three Pritchard pumphouses; the major amount of servicing was performed by the Pritchard system.

Mobile equipment at Bergstrom included four MH-2 and six MV-2 hose carts*, and twelve F-6 and two R-2 refuelers.

b. Bulk Storage and Receiving Area

The two floating roof-tanks were designated as B-14 (20,000 bbl) and C-1 (13,000 bbl). Both tanks had metal-to-metal roof seals and closed center roof drains with a jointed pipe extension to the foot valve, which was normally left open. No problems with roof seal freezeup were reported, and apparently no calcium chloride had ever been needed. Sometimes ethylene glycol was added to the roof drains as a precautionary measure.

Each tank had a single active fill-issue line; this was an 8" line entering horizontally, 13" (centerline) above the tank bottom. The drawings showed the lines as going directly in, not turned up or down. Tank B-14 had an internal-flapper fire safety valve on the open end of this line, which would appear to deflect incoming fuel downward. Tank C-1 had a fire safety valve inside the pipe outside the tank.

Each tank, according to the drawings, had a water drain line entering through the side and immediately turning down and terminating within 1/2" of the bottom. This line was shown as 1-1/2" pipe on Tank B-14 and 3" pipe on Tank C-1. So far as could be determined, neither of these tanks had either a sloped bottom or a sump. Bergstrom local instruction O.I. 144-8 called for a maximum water bottom of 1-1/2" in these tanks, but a 2" level was considered more practical. The water gage readings were 1-5/8" to 1-3/4" during the survey. So far as could be determined, no water was drained from these tanks during the week of the survey, except for the survey sampling.

It was stated that the tanks were inspected on a three-year schedule and cleaned when necessary, and that only an inch of sludge had been found on the last inspection.

Ideally, the two tanks would be alternated daily so as to get some 24 hours of settling time on each. However, it was evident that insufficient storage capacity was available to permit this ideal schedule, and it appeared questionable whether even four hours of settling could be achieved most of the time.

---

*In this report, the term "hose cart" is applied to any unit carrying hose to connect from hydrant to aircraft, whether or not it has filters and meters, and whether it is towed or truck-mounted.

The transfer pumps in the bulk storage pumphouse were used for unloading tank trucks into bulk storage, for transferring from bulk to operating storage, and for supplying fuel to the truck fill stand. Gravity flow from bulk to operating storage was feasible and sometimes used. Because of the piping arrangement, it was impossible to unload trucks into one bulk tank and at the same time transfer fuel from the other bulk tank to operating storage.

So far as could be determined during the survey, no visual samples were taken from incoming trucks, although later it was stated that this check is performed regularly. It was also said to be regular practice to drain off a few gallons from the drain or manifold of each truck, which could be an effective means of detecting any gross amounts of free water or sludge. There were said to be checked daily. It was also stated that a line sample was taken for visual observation whenever a transfer was made from bulk to operating storage.

Bulk tank temperatures were running about 53°F at the time of the survey and were said to reach 80-90°F during the summer.

c. Operating Storage Areas

The Panero pumphouse area included twelve 25,000-gallon underground tanks, each with 300-gpm deep-well pump and filter-separator. Of the eighteen Panero filter-meter pits and hydrants, only nine were active. A single defuel tank was located at the end of the row of filter-meter pits. The Panero system was used primarily for servicing small aircraft.

Of the three Pritchard pumphouses, one had eight 50,000-gallon tanks and the other two each had six 50,000-gallon tanks. Each tank was equipped with the usual 300-gpm deep-well pump and filter-separator. The gaging hatch on each tank was about 1/4 to 1/3 of the distance from one end of the tank. There was some question as to whether the gaging pipes extended all the way to the bottom of the tank. The tanks had been installed level originally. The water level was gaged each day and pumped off when it exceeded 1/4"; apparently water removal was seldom necessary. There was no particular designation of any of the tanks as defuel tanks; any of them could be used for defuel as dictated by scheduling. Tank inspection was on a three-year basis. At least one of the Pritchard systems was equipped for rapid defueling, and it is believed that all three were so equipped.

d. Aircraft Fueling and Defueling Operations

Refueling was ordinarily accomplished with two pumps, giving a nominal flow rate of 600 gpm. However, operating personnel stated

that it was fairly common practice to use three pumps, presumably because of low output of the individual pumps.

It was understood that whenever an aircraft was removed from the alert area, it would be partially defueled. This appeared to represent the major portion of the defueling accomplished at this base.

It appeared that the MH-2 and MV-2 units were both used for refueling and defueling. There was some confusion among operating personnel on the role of these hose carts in defueling operations. So far as can be gathered from the applicable T.O.'s and from observation of the units, the fuel flows through the filter-separator and meter in the normal direction during defueling as well as refueling. However, most Bergstrom fuels personnel said that the filter-separator was bypassed during defueling and in fact stated that the MH-2's had been modified to permit such bypassing. This view was also expressed at several other bases surveyed in connection with another contract, but we have been unable to document this situation.

e. Mobile Servicing Equipment

As stated above, Bergstrom's four MH-2 and six MV-2 hose carts are used in both refueling and defueling operations in the Pritchard system. The only problem mentioned on these units was warping and leakage of the filter-separator end doors on the MV-2's.

The twelve F-6 and two R-2 refuelers were used mainly for servicing small aircraft, for defueling, and for topping-off operations. It was mentioned that some stripping of the Thermoline interior coating had been encountered when the anti-icing additive was introduced. Also, there was some mention of trouble with damaged R-2 hose reels caused by pressurizing the hoses while they were on the reels.

f. Filter-Separators

One filter-separator at the bulk storage pumphouse, in the line to the truck loading rack, was not identifiable.

The filter-separators in the Panero pumphouse were originally Erie dehydrators that had been converted with Briggs BFS 26-300 kits (A-870 elements). The Panero filter-meter pits had conventional micronic filters.

Pritchard Areas D and E each included four Bowser 903 filter-separators and two Warner-Lewis FLS-245ANW filter-separators,

300 gpm each. Area F had no Bowser units, but eight of the Warner-Lewis units. According to nameplate data, the Bowser units used 47B37 elements with external sock, which were to be changed at 3.5 psi differential. The Warner-Lewis units called for CC-5 cartridges with internal sock, element change at 12 psi differential. Maintenance personnel mentioned difficulty with the end-sealing arrangement in the Warner-Lewis elements, which is a neoprene ring that seals when the element is screwed hand-tight into the fitting.

The Bergstrom MH-2 hose carts carried the usual Warner-Lewis filter-separator with individual coalescer and separator elements, the coalescers being mounted above the separators. The MV-2's carried the Permadry Model 520-42 unit with stainless steel case containing first-stage (sock) elements, second-stage coalescers with bronze inserts, and "final barrier" of synthetic fabric screen.

Most of the discussion of filter-separators at Bergstrom centered around the criteria for changing elements. It was stated by the Fuels Officer that the SAC criteria are 18 months, 8 psi differential (regardless of manufacturer's recommendations), or a gallonage figure. Although these criteria cannot be verified either in SACM 67-2 or in the T.O. literature, it appeared from discussions with maintenance personnel that the 8 psi criterion was applied at least to all fixed filter-separators, regardless of nameplate recommendations.

The situation was further complicated at Bergstrom by the use of differential pressure gages that were not reliable. Apparently the maintenance personnel had given up attempting to keep these gages in working order. Similar difficulties with the gages of this particular manufacturer have been reported by other bases. At Bergstrom, it was stated that the gages often recorded negative differential pressures under flow conditions. Many of the gages that were observed during the survey were either stuck or reading incorrectly; others were vibrating badly. One gage was observed to be stuck at 8 psi under no-flow conditions, with the balance line open. Under these conditions, little or no reliance could be placed on the differential pressures as criteria for changing elements. It was stated that every instance of filter plugging evidenced by differential pressure readings had been detected sooner by excessive solids content in the effluent. Thus, there was the opinion that the gage readings were simply an extraneous bit of record keeping. In view of the poor performance of these particular gages, such opinion seems justified. Apparently there had been some effort made in the past to pass this complaint through the proper channels, but no corrective action had been taken.

g. Laboratory Control and Sampling

The Bergstrom laboratory was equipped to run KF-3 water analyses and Millipore solids determinations. At the time of the survey, they had not set up for anti-icing additive determinations.

It was gathered that some difficulty had been encountered in keeping up with the number of refueling samples required by SACM 67-2. Since this requires a sample from each Panero filter-meter pit, Pritchard hose cart, or refueler every day it is used, the volume of sampling and analysis could become quite excessive. It was indicated that weekly sampling of each unit was more in line with their laboratory capabilities at that time. It was stated that a sample was drawn for visual observation at each aircraft servicing, but no retain samples or records were kept.

It was said that samples would be taken at each defueling operation by the fuel distribution section, but only to be examined and discarded. One of the Bergstrom local S.O.P.'s does specify such visual examination of truck defuel before it is dumped into the Panero defuel tank.

In the case of aircraft sump samples, they were attempting to schedule one B-52 and one KC-135 per morning, but apparently the flight schedules interfered more often than not. The sump samples were taken by laboratory personnel, who first would draw about one gallon from the sump and then bring it back to the laboratory to decant one quart for analysis (water and solids) and measure the amount of water in the bottom, which might run from 0 to 600 ml. No composite sump samples were collected; normally only one sump per aircraft was sampled. The B-52's were usually sampled at one of the outboard wing tanks and the KC-135's at a body tank. The B-52 samples were said to be almost invariably dirty and the KC-135 samples quite clean.

The laboratory would have no knowledge or control over the sump draining by the aircraft servicing crew; hence, the amount of dirt or water in the gallon drawn by lab personnel would not be especially meaningful. The aircraft servicing crew would normally drain all sumps 1.5 to 8 hours before takeoff.

h. Local Operating Instructions

The local instructions, supplementing SACM 67-2 and the applicable T.O.'s, are issued at Bergstrom as Office Instructions (OI's), signed by the Base Fuels Officer. These appeared to be fairly extensive and up to date. Abstracts of the most important points from these OI's relating to quality control and sampling are given in the following paragraphs.

OI 144-8, 17 Apr 62. Water Bottoms. Bulk storage tanks are to be gaged daily, and any excess over 1-1/2 inches will be drawn off. Operating tanks are to have water drawn off whenever it exceeds 1/4 inch.

OI 144-10, 17 Apr 62. Receipt of Fuel. "A composite sample will be removed from the (truck) shipment in a clear glass bottle ..... checked for color, contamination, and unusual odors. If the sample appears satisfactory, it will be poured back into the unit. If ..... unsatisfactory, the Base Fuels Officer will be notified immediately."

OI 144-12, 17 Apr 62. Maintaining Quality Control of Defuels. Before any fuel is transferred to the Panero defuel tank, the servicing vehicle operator is to take a sample and determine whether the fuel is contaminated, confirming by laboratory tests if necessary. Fuel found to be contaminated is to be turned over to the Base Fire Department. When an aircraft is defueled directly into the Panero defuel tank, the procedure is similar except that fuel found to be contaminated must be transferred to a servicing vehicle for delivery to the Fire Department. Sampling of the Panero defuel tank is also specified before any transfer back to bulk storage.

OI 144-15, 17 Apr 62. Extracting Samples for Laboratory Analysis. Specifies daily sampling of each filter system (fueling unit, hydrant filter meter pit, and hose cart), but if this creates an excessive workload, at least one sample from each pumphouse and at least one sample from a refueling unit and hose cart is to be taken, rotating so that each filter system is tested at least weekly. Samples are to be taken from the servicing nozzle to represent fuel that has passed through the filter at its normal operating flow rate. Each sample container will be properly cleaned and rinsed with fuel being sampled, before actual filling. Sample containers will be marked with ..... any additional pertinent data such as stormy or dusty conditions. The samples specified in this OI are for analysis for water and particulate solids.

OI 144-17, 17 Apr 62. Receiving in Floating-Roof Tanks. Bulk storage tanks must settle at least four hours before transfer to the hydrant systems. At least one hour settling time is required before an "after" gage is taken.

OI 144-18, 17 Apr 62. Quality Control Section. Quality control personnel are (among other duties) to "maintain quality control records on all fuel tanks, filter systems, and sample results ..... make periodic inspections of all base fuels fixed facilities and mobile equipment. Periodically, quality control personnel will check operator performance for compliance with quality control directives." This OI also gives directives for frequency of sampling, which are same as SACM 67-2.

OI 144-27, 17 Apr 62. Operation of Differential Pressure Gages on Filter-Separators. Gives procedure for opening valves to read gages and keeping records on AFTO Form 50D. Readings are to be taken at full rated flow and normal operating pressure. When a decrease in pressure is noted, Civil Engineering maintenance personnel are to be notified.

4. Bergstrom Survey Sampling and Analysis

a. General

Samples were taken at various points in the system for microbial assays and chemical and physical tests. Samples were taken directly into sterile sample containers wherever possible (e.g., tank drains, line samples, dip samples, etc.). Other tank sampling was performed with a hand pump and aluminum tubing. Although this was an effective means of sampling at any desired depth, the pump was somewhat difficult in operation and undoubtedly contributed to cross-contamination of samples in spite of thorough rinsing.

The sampling and analytical data are described in Tables 1-10. Test methods are described in Appendix A.

b. Incoming Fuel Samples

Incoming tank trucks were sampled by top dipping and also by attempting to catch the first drainings from the manifold or drain valve. The top samples (Table 1) were quite clean, and almost all had less than 2 mg/gal solids. The exception, Sample No. 5, had 7.4 mg/gal and some free water. The bottom drain samples, as expected, showed a wide variety of foreign material. However, none of them had any really large amounts of solids, and the most water that could be collected from any of the trucks was only 5 ml. Thus, it appears that none of the suppliers was introducing any major amounts of contaminants into the Bergstrom system at the time of the survey. None of the suppliers had any advance notice of the survey, and it can be assumed that the cleanliness was normal.

The water separometer tests (Table 2) indicated that the truck deliveries were of good quality with respect to water-separating characteristics.

c. Bulk Storage Samples

The Bacon bomb sampler available at the base proved to be unsuitable for taking samples at any depth, because of leakage and the lack of sufficient length of chain. Therefore, the bulk tank samples were

TABLE 1. INCOMING TRUCK SAMPLES AT BERGSTROM AFB

Sample No.*	Supplier	Dip or Drain	Millipore Solids, mg/gal	Visual Observations on Settled Samples
4	Danaho	Dip	1.3	Fair amount of particles
5	Danaho	Dip	7.4	Water drops on bottom; some particles
6	Howell	Dip	0.4	Small amount of water; some particles
7	Howell	Drain	-	Some rust chunks in bottom; cloudy water on bottom and sides of bottle (zero microbial count in water)
8	Danaho	Drain	-	One large red flake, miscellaneous particles
9	Danaho	Drain	-	Considerable particles
10	Danaho	Drain	-	Considerable particles; fuel greenish
11	Danaho	Drain	-	(Same as 10, after flushing line) - Lots of small particles; no green color in fuel
12	Danaho	Dip	0.8	Numerous small particles, possibly lint
13	Danaho	Drain	-	Drops of water on bottom; assorted trash
14	Danaho	Dip	0.0	One fair-sized piece of lint, one small black flake, and some fine lint
15	Danaho	Dip	-	Relatively clean except for numerous fine particles, probably lint
18	Cardinal	Dip	0.4	Very clean sample, except one metallic particle, possibly one or two other particles
19	Cardinal	Drain	-	Few rust flakes and water on bottom of bottle
20	Danaho	Drain	-	Considerable trash, apparently rust
21	Danaho	Drain	-	Slight amount of fibers and trash; trace of water on bottom (fungus count per ml: water 1, fuel 0)
22	Danaho	Drain	-	Dirty; approx. 3-5 ml rusty water
23	Danaho	Drain	-	(Same as 22, after draining 2 gal) - Small amount of water and rust on bottom
24	Danaho	Drain	-	Relatively clean; small amount of trash and possibly water
25	Danaho	Drain	-	Relatively clean; small amount of trash
26	Humble	Dip**	0.0	Clean except for few lint particles
27	Humble	Drain***	-	Small amount of trash
28	Humble	Drain***	-	Considerable trash; possibly water on bottom
29	Humble	Dip	-	Very small amount of trash, possibly trace water
30	Howell	Drain	-	Yellow-green fuel; numerous large red flakes and other trash; some water on bottom
31	Humble	Drain	-	Very little lint; possibly trace of water
32	Howell	Dip	-	Yellow-green fuel; trace of water on bottom; small amount of lint
33	Howell	Drain		Yellow-green fuel; numerous large red flakes and other trash; some water on bottom

*Samples are listed in order drawn. Samples 1-15 were drawn on 8 January 1963, and Samples 18-33 on 9 January 1963. All samples taken direct y in quart bottles.

**Observed a very slight haze when drawn.

***Samples 27 and 28 are from same truck; when the first drain sample came dirty, a second sample was drawn.

TABLE 2. WATER SEPAROMETER TESTS ON BERGSTROM AFB FUELS

Sample No.	Source	WSI*
80-81	Danaho truck, top dip	99
82-83	Howell truck, top dip	95
84-85	Cardinal truck, top dip	97
86-87	Robertson (Humble) truck, top dip	98
88-89	Howell truck, top dip (yellow-green)	100
90	Refueling truck fill stand	100

*Water separation index (WSI) was determined on a standard CRC water separometer, using the current Standard Method 3255-T of FTS-791a.

TABLE 3. BULK FUEL STORAGE SAMPLES FROM BERGSTROM AFB

Sample No.*	Source	Millipore Solids, mg/gal	Visual Observations on Settled Samples	Total Count on Fuel	
				Method	No./ml
3	Tank B-14, bomb sample 15' from bottom (bomb dirty) - tank had not received fuel for 3 days		Large amount of transparent particles	Millipore Agar	0 0
16	Tank C-1, bomb sample 9' from bottom (sample taken immediately after unloading several trucks into this tank	13.7	Slight yellow color; lots of trash, fibers, and miscellaneous particles; sample clear	Millipore	0
17	Pumping line from Tank B-14 while pumping to operating storage	0.0	Clear; considerable lint and other fine particles; possibly some water	Millipore	0
34	Tank B-14, bomb sample 20' from top (probably 5-10' off bottom) - tank had not received fuel for 4 days, but had issued fuel the previous evening	1.8	Numerous lint particles, but bottom of bottle clean	Millipore Agar	0 0

*Samples 3, 16, and 17 were taken 7 January 1963 (Monday); both tanks had remained over the previous weekend without receiving fuel, but may have issued fuel to operating storage. During this day, C-1 was receiving fuel, and B-14 was idle (Sample No. 3) until evening, at which time it was used to issue fuel to operating storage (Sample No. 17 drawn at this time).

Sample No. 34 was taken 8 January 1963 (Tuesday) in the morning, at which time Tank B-14 had still not received any incoming fuel.

TABLE 4. BULK STORAGE TANK BOTTOMS FROM BERGSTROM AFB

Sample No.	Date	Source	Visual Observations on Settled Samples
1	7 Jan 63	Tank C-1 water drain; tank had received one load of fuel earlier this day	90% cloudy yellow water; small amount of rusty sediment; small amount of material at interface
2	7 Jan 63	Tank B-14 water drain; no fuel had been received in this tank for 3 days	95% cloudy, slightly yellow water; little rust on bottom; little rusty sludge at interface; top 10-15% of water appears more cloudy, as if emulsified
49	9 Jan 63	Tank C-1 interface, hand pumped from 2-1/4" off bottom	30% cloudy water; 70% fuel with fine suspended material; 1/8" mat of rust-colored sludge at interface
58	10 Jan 63	Tank B-14 interface, hand pumped from 1-7/8" off bottom; tank had settled overnight since receiving fuel	70% cloudy yellow water; rust on bottom; rusty sludge at interface; top 5-10% of water is much more cloudy (possibly emulsified)
61	10 Jan 63	Tank C-1 water drain, after drawing off 500-1000 gal of water	80% cloudy yellow water; rust on bottom; fair amount of rusty sludge at interface
62	10 Jan 63	Same (second sample)	Appearance similar to No. 61
63	11 Jan 63	Tank B-14 water drain while tank was receiving fuel; morning water gage level was 1-5/8"	Almost all cloudy yellow water; rust on bottom; rusty sludge on top

TABLE 5. ANALYSES AND COUNTS ON BULK STORAGE TANK BOTTOMS FROM BERGSTROM AFB

Sample No.*	1	2	49	58	61	62	63
Water layer composition, wt %:							
Glycerin	3	2	-	-	2	2	2
Methoxyethanol	20	21	-	-	20	20	21
Water	77	77	-	-	78	78	77
Chloride in water layer, mg/liter	70	53	-	-	80	-	-
Total counts per ml:							
Water layer, agar method	10	0	10	0	-	0	-
Water layer, Millipore method	1	2	0	<1	0	0	0
Water layer, anaerobic	0	0	-	-	-	-	-
Fuel layer, Millipore method	0	0	0	0	0	0	-
Interface, agar method	-	-	40	-	-	0	-
Interface, Millipore method	-	-	7**	6**	10**	3	12**
Fungus counts (Sabouraud's) per ml:							
Water layer - fungi	15,2	3,2	-	1	1	-	-
- bacteria	17,6	40	-	-	16	-	-
Fuel layer - fungi	0	4	-	-	9,1	-	-
- bacteria	8	0	-	-	1,2	-	-

*All samples taken in sterile bottles, but taken through nonsterile hand pump in the case of Samples 49 and 58. See Table 4 for details on sampling locations.

**Total of this number of colonies obtained from a small sample (indefinite volume) of the interfacial material.

TABLE 6. OPERATING STORAGE FUEL AND BOTTOMS SAMPLES FROM BERGSTROM AFB

Sample No.	Source*	Millipore Solids, mg/gal	Visual Observations on Settled Samples
35	Panero Tk B-13 (defuel), bottom	-	Blue-colored fuel, considerable amount of fibers and trash
36	Pritchard F/S E-1, fuel drawn from water drain line (F/S operating just before)	-	Fuel darker yellow than usual; one large black particle, few other particles
37	Ditto, fuel outlet line	-	Fair amount of fine lint, one large piece of debris; bottom otherwise clean
38	Pritchard Tk E-1, bottom	-	Rusty water on bottom and sides
39	Same	-	Dark brown liquid and solids on bottom; rusty water on sides
40	Same	-	About 5 ml of rusty water; rust on sides
41	Pritchard Tk E-2, bottom**	-	Bottom and sides covered with water and rust
42	Pritchard Tk E-6, bottom	-	About 10 ml of cloudy, rusty water
43	Pritchard Tk E-4, bottom	-	About 50 ml of cloudy, rusty water; large particles floating at interface
44	Pritchard Tk F-5, bottom**	-	Bottom covered with cloudy water and solids
45	Pritchard Tk F-6, bottom**	-	Same, but only few large solid particles
46	Pritchard Tk F-2, bottom (filled previous evening)	-	Bottom covered with rust and possibly water; rust disperses readily, giving great amount of large and small particles
59	Pritchard Tk E-1 defuel, about 2' below fuel level, taken 3 hr after rapid defuel-	1.2	Bottom covered with water; considerable trash when shaken up; settles clear rather rapidly
60	Same, 5' below fuel level	2.5	Similar to No. 59

*All tank samples were taken by hand pump.

**Issue to aircraft from this tank had been completed shortly before sampling.

TABLE 7. ANALYSES AND COUNTS ON OPERATING STORAGE FUEL AND BOTTOMS SAMPLES FROM BERGSTROM AFB

Sample No.*	38	39	40	41	42	43	44	45	46	59	60
Millipore solids, mg/gal	-	-	-	-	-	-	-	-	-	1.2	2.5
Water layer composition, wt %:											
Glycerin	-	-	-	-	-	4	-	-	-	-	-
Methoxyethanol	-	-	-	-	-	23	-	-	-	-	-
Water	-	-	-	-	-	73	-	-	-	-	-
Total counts per ml:											
Water layer, agar method	2	-	-	-	-	40	-	-	-	-	-
Water layer, Millipore method	3	-	-	11	5	14	-	-	-	-	-
Fuel layer, Millipore method	0	-	-	0	0	0	0	0	0	0	0
Interface, agar method	-	120	-	30	20	-	-	-	0	-	-
Interface, Millipore method	-	31	-	**	10	-	-	-	-	-	-
Fungus counts (Sabouraud's) per ml:											
Water layer - fungi	4,0	0.2	0	-	9,6	-	-	4,2	-	-	-
- bacteria	-	-	5	-	0	-	-	-	-	-	-
Fuel layer - fungi	-	0	-	1	3,2	6,3	-	3	0	-	-
- bacteria	-	30	-	2	0	0	-	0	21	-	-

*All samples taken in sterile bottles, but taken through nonsterile hand pump. All samples are from operating storage tanks, and all but Nos. 59 and 60 are bottom samples. See Table 6 for details on sampling locations.

**Colonies obscured by debris.

TABLE 8. REFUELING LINE SAMPLES FROM BERGSTROM AFB

Sample No.	Source	Millipore Solids, mg/gal	Visual Observations on Settled Samples
47	B-52 refueling nozzle (local aircraft)	0.0	Clean except for 5-10 lint particles
48	KC-135, Tks 1 and 2, refueling line sample	0.0	Numerous lint particles; bottom clean
50	B-52, Tks 3 and 4, refueling line sample	1.9	Numerous lint particles
51	KC-135 No. 2594, refueling line sample	3.9	Clean except for a few small particles

*All of above samples were drawn by Bergstrom personnel. Total counts on Samples 48 and 50 were zero (both agar and Millipore methods). Sample 50 was also cultured for fungus count, which was also zero.

TABLE 9. AIRCRAFT SUMP DRAIN SAMPLES FROM BERGSTROM AFB

Sample No.	Source	Millipore Solids, mg/gal	Visual Observations on Settled Samples
52	KC-135 No. 2592 sump drain		Numerous small particles; bottom clean
53	Same		Numerous lint particles
54	Same	0.7*	Clean except for few lint particles
55	Same		Some small black particles and lint
56	Same		Numerous particles of lint and some red debris

Note: The above series (Nos. 52-56) represents a single sump drain of one gallon, taken from aircraft that had presumably been refueled on the previous day. Sample was transferred from original one-gallon can (nonsterile) to sterile bottles after 4 hours.

57	KC-135 No. 2592, sump drain (quart sample taken immediately after Nos. 52-56)	0.0	Fair amount of lint, possibly some free water (appears to be few drops on bottom); sample clear
64	B-52D No. 0078, sump drain from left outboard wing tank		Bottom covered with water, easily dispersed; water reasonably clean
65	Same		About 300 ml of fairly clear yellow water, 100 ml of fuel; pinkish foamy material at interface; traces of rust on bottom
66	Same		Same as No. 64
67	Same		About 60 ml of cloudy yellow water; pinkish foamy material at interface

Note: The above series (Nos. 64-67) represents a single sump drain of one gallon, taken from aircraft that had been refueled the previous evening. Sample was transferred from original one-gallon can (nonsterile) to sterile bottles after 1 hour.

68	B-52D No. 0078, sump drain (quart sample taken immediately after Nos. 64-67)	2.3	Water drops on bottom and sides

*On total sample (Nos. 52-56).

TABLE 10. ANALYSES AND COUNTS ON AIRCRAFT SUMP DRAIN SAMPLES FROM BERGSTROM AFB

Sample No.*	52-56	57	65**	67**	68
Millipore solids, mg/gal	0.7	0.0	-	-	2.3
Water layer composition, wt %:					
Glycerin	-	-	1	-	-
Methoxyethanol	-	-	27	-	-
Water	-	-	72	-	-
Chloride in water layer, mg/liter	-	-	52	50	-
Total counts per ml:					
Water layer, agar method	-	-	2300	2600	-
Fuel layer, Millipore method	0	0	-	-	-
Interface, agar method	-	-	>3450	-	-
Fungus counts (Sabouraud's) per ml:					
Water layer - fungi	-	-	5,12	12,0	-
- bacteria	-	-	2,0	20,2	-
Fuel layer - fungi	-	-	4	0	0
- bacteria	-	-	0	0	0

*Samples 52-56, 65, and 67 were originally taken as one-gallon sump drains (nonsterile can) and later transferred to sterile quart bottles. Samples 57 and 68 were drawn into sterile bottles originally. See Table 9 for details on sampling points.

**The water bottoms and interface material from Samples 65 and 67, which required dilution prior to culturing, were dispersed by adding Tween 80 when diluting.

taken either by hand pump or through the water drain line. The fuel samples (Table 3) showed that considerable stir-up was caused by unloading tank trucks into Tank C-1, giving a solids content of 13.7 mg/gal about 9 feet off the bottom. Samples taken after settling showed satisfactorily low solids contents. Not enough samples were taken to get any idea of settling rates.

The tank bottom samples (Table 4) indicated that their appearance was somewhat similar whether taken through the gaging hatch by hand pump or whether drawn directly through the drain line. The drain line samples when drawn were highly emulsified on passing through the valve, but settled out after standing. Since some fuel was obtained in most of the drain line samples, it appears that the water gage levels were being held about as low as possible in these tanks without losing large amounts of fuel during water draw-off. The interface samples shown in Table 4 were taken by positioning the sampling tube at the interface as determined by water gage paste, and also slightly above and below the presumed position. These samples contained only minor amounts of sludge or heavy emulsion, indicating that the tank interface was fairly clean; however, this evidence is not conclusive because of the possibility of channeling at the interface while the samples were being drawn.

The analytical data on the water bottoms (Table 5) indicate 2 to 3% glycerin. The 20-21% methoxyethanol content is fairly near equilibrium concentration for water in contact at 45-55°F with fuel containing 0.1% additive. This would indicate that there had been little dilution with rain water in the week or two prior to the survey, which is borne out by the lack of any heavy rains during that period.

The chloride contents of the three water bottoms samples that were analyzed were relatively low, 53 to 80 mg/liter, in comparison with a commonly accepted maximum of 250 mg/liter for drinking water and a normal chloride content of 50 mg/liter for river waters and city water supplies. Therefore, it appears that there was no problem with access of salt water to these tanks. The fact that two of the suppliers used a rock salt or calcium chloride drier on their JP-4 blending and loading system had given some cause for concern that these units might occassionally malfunction and unload brine into the fuel stream.

The microbial counts were all very low on these water bottoms samples, regardless of culturing method or whether the sample was taken from the water layer or from the interfacial material. Samples taken from these same tanks in April indicated some renewed growth, although the total counts were still quite low:

	Count per ml (agar)	
	Jan 1963	Apr 1963
Tank B-14	0	630
Tank C-1	10	860

d. Operating Storage Samples

Data on samples taken from underground operating tanks (Table 6) indicated that there was very little water in these tanks; only No. 43 showed as much as 50 ml water in the quart sample. In view of the limited amounts of water on these tank bottoms, it was surprising to find appreciable amounts of water stirred up in one of these same tanks some three hours after it had received defuel from a KC-135 (Samples 59 and 60). These samples, like the others, were taken through the gaging hatch and hence may not be representative of the tank contents. However, it is still surprising to find an appreciable amount of water stirred up near the fuel surface some three hours after the defueling had been completed. The solids contents of these samples were low, although they appeared rather dirty.

The only sample with enough water for analysis was No. 43, in which the glycerin and methoxyethanol contents were slightly higher than for the bulk storage samples (Table 7). The microbial counts were all low, the highest being 120 per milliliter on the interfacial material from Sample No. 39 (Tank E-1 bottoms).

e. Refueling Line Samples

The only refueling samples that could be obtained were four samples drawn by Bergstrom personnel (Table 8); it is believed that these all came from sampling cocks on single-point nozzles, although there was some confusion on the sample descriptions. All of these samples had less than 8 mg/gal of solids. Numerous lint or fiber particles were evident in two of the samples on visual observation. It should be mentioned that the sample bottles used here had been prewashed in the laboratory but were not "particle-free." This suggests either that the hose cart filter-separators at Bergstrom were passing large amounts of visible fibers, or else that the SACM 67-2 criterion of "not more than four or five visible fibers" is meaningless unless standards are set up for bottle cleanliness and sampling procedures.

As expected for relatively clean, dry fuel, no bacterial or fungal contamination was found in these samples.

f. Aircraft Sump Drain Samples

The aircraft sump drain samples (Table 9) were taken by Bergstrom laboratory personnel. Samples 52-56 represent a gallon drained from a KC-135, and Sample 57 represents the quart sample taken immediately after the gallon drain. Similarly, Samples 64-67 represent the first gallon from a B-52D sump, and Sample 68 the following quart. Although it was first thought that this represented normal Bergstrom sampling practice, it was later learned that their quart for analysis is taken from the top of the first gallon drawn from the sump.

The KC-135 samples were quite clean, which was said to to typical. Curiously, the final quart (No. 57) showed a trace of water, although the previous gallon seemed to be dry. In the case of the B-52D samples, some dirt and a total of about 400 ml of free water was obtained. After drawing the gallon, there was some free water even in the final quart (No. 68). This sort of occurrence raises the question of how to interpret laboratory analyses of such sump drain samples, since the presence or absence of free water is strictly a function of the draining procedure.

The 1% glycerin content of the B-52 water (Table 10) is significantly lower than the 4% observed in a Bergstrom operating tank, and the 27% methoxyethanol content of the B-52 water is significantly higher than the 20-23% observed in the base fuel system. The chloride content of only 50-52 mg/liter indicates no particular salt water contamination. The microbial counts on the B-52 water samples were the highest observed at Bergstrom, but still in the relatively low range of a few thousand per milliliter.

It should be noted that these two series of sump drain samples matched up very well with previous statements of Bergstrom personnel on what was typical of the samples they had obtained.

5. Summary of Bergstrom Operations

Bergstrom, like many Air Force bases, has bulk storage tanks that do not permit complete removal of water. However, the condition of the fuel, water bottoms, and interface in these tanks was found to be quite good. Essentially no viable microorganisms were found in these tanks in January 1963, and the counts in April 1963 were only a few hundred per milliliter. The methoxyethanol content of the water bottoms was running near equilibrium (20-21%) at the time of the survey. It appears that the bulk storage capacity of Bergstrom was insufficient to permit even four-hour settling of fuel receipts in all cases before transferring to operating storage, although overnight settling was regarded as desirable.

Incoming fuel appeared to be of good quality, both as to contamination level and water separometer index.

The Pritchard hydrant tanks at Bergstrom were found to contain very little water, and here again there was essentially no microbial contamination. The presence of dispersed water in the upper levels of one tank some three hours after receiving defuel was somewhat disturbing.

The Pritchard filter-separators were of two types, with nameplate recommendations for element change at 3.5 and 12 psi; however, Bergstrom was applying an 8-psi criterion to both types. There had been considerable difficulty with the differential pressure gages on these filter-separators, and little or no reliance was placed on their readings.

There did not appear to be any regular examination of samples from incoming fuel shipments, although it was stated that this was done. The frequency of sampling throughout the system for base laboratory analysis was not yet up to that required by SACM 67-2.

The few samples drawn from refueling operations indicated adequate fuel cleanliness, except that it was evident that standards for sample bottle cleaning and/or the appearance of "fibers" should be redefined. The sump drain samples confirmed the general opinion that the B-52D's usually showed some water and dirt and that the KC-135's were relatively clean. It was evident that scheduling and interpretation of sump draining procedures will have a major effect on the results obtained. The water from the B-52D sump had the highest microbial count of any of the samples taken at Bergstrom, but this was still on the order of only a few thousand per milliliter. In general, the sampling and analysis indicated that most of the base fuel system was very nearly sterile, and the viable microorganisms that were found could very well be "strays" that had come into the fuel system just before the samples were taken.

The general cleanliness level and housekeeping in the Bergstrom fuel system were quite good, reflecting good control over the whole operation. The only serious shortcoming was the lack of any meaningful pressure differential readings on the fixed filter-separators.

C. Carswell AFB

1. General

The principal operating aircraft at Carswell were B-52F's and B-58's. It was indicated that a considerable amount of defueling was done in

the case of the B-58's, particularly whenever a particular aircraft would change from training to alert status. Most of the defuel was probably of Carswell origin, although aerial refueling from KC-135's from other bases might introduce extraneous fuel into the base fuel system. It was indicated that defueling of transient aircraft was almost nonexistent.

Most of the aircraft fueling operations were carried out in the evening and night shifts, and all of the fuel system inspection and routine maintenance work was performed on the day shift. The maximum fuel issues to aircraft were roughly 180,000 gal/day during the week and 240,000 gal/day on weekends, as compared with an over-all average of 125,000 gal/day.

2. Fuel Supplies

a. General

Fuel was being received by tank car and tank truck at the time of the survey, and there were no known plans for pipeline deliveries. The contract amounts for the six-month period ending 31 March 1963 were as follows:

Supplier	Contract Amount, Million Gallons	Method of Delivery
Premier Oil Refining Co. of Texas, Fort Worth (refinery)	13.0	70% by tank car, 30% by tank truck, from refinery
American Petrofina Co. of Texas, Mt. Pleasant, Texas (refinery)	8.9	Pipeline from refinery to bulk terminal at Grapevine, Texas, then to Carswell by tank truck
Petroleum Refining Co., Lueders, Texas (refinery)	1.1	Tank truck from refinery

Petroleum Refining Co. was hauling in their own trucks, and the other two companies were supplying fuel f.o.b. refinery or terminal for Government-contracted transportation to Carswell. The Government-owned tank cars bringing in fuel from Premier were mostly bare steel, but a few Navy tank cars were said to be interior-coated. Most of the contractors' tank trucks had aluminum tanks. Of the eight Petroleum Refining Co. trucks that were reserved for JP-4 service, six were bare steel and two were interior-coated with Cook material.

No serious difficulties were reported by Carswell personnel with incoming fuel quality, except that there had been some problems with filter and filter-separator elements at the time the anti-icing additive had been introduced. Also, there had been some difficulty a few months earlier with excessive amounts of rusty debris in tank cars and with some dirty tank trucks.

The fuel suppliers for the next contract period starting 1 April 1963 were as follows:

Debco Corp. (Abilene)	1.4	million	gallons
Bell Oil and Gas (Ardmore, Okla.)	2.37	"	"
Premier (Ft. Worth)	4.5	"	"
American Petrofina (Grapevine)	3.0	"	"
Petroleum Refining (Lueders)	0.83	"	"
Great Western Producers	1.3	"	"

These contracts were for a three-month period.

Information on the fuel suppliers at the time of the survey is given in the following paragraphs.

b. Premier Oil Refining Co. of Texas

The Premier JP-4 consisted of straight-run cuts from Ranger crude, including a sweetened kerosine, a Murox-sweetened narrow-cut naphtha, and an untreated full-cut gasoline, the latter being added only as required to adjust vapor pressure. No additives (other than anti-icing) were used. The fuel blend stocks were pumped to two 10,000-bbl fixed-roof tanks for blending and storage. On the way to these tanks, the stocks passed at about 250 gpm through two 4' X 40' salt towers in series, then through a fabric filter, and then through an injection system where the anti-icing additive was added. The blending and storage tanks were blanketed with natural gas to exclude moisture, as was their additive storage tank. The 10,000-bbl fuel tanks had nominally flat bottoms with a sump for water drawoff - but not necessarily at the low point. The suction lines in these tanks were fixed, about one foot off the bottom.

c. American Petrofina Co. of Texas

The Petrofina JP-4 was cut from fairly heavy crudes, 21-26 API (not otherwise identified). All JP-4 components were straight-run cuts with caustic treating only: kerosine, Stoddard solvent, and light SR gasoline. In addition to the anti-icing additive, metal deactivator at 1 lb/1000 bbl was being added to correct an earlier problem with fuel coker

preheater deposits, thought to be caused by fine rust not removed by filters. The fuel base stocks and the additives were blended in an 18,000-bbl fixed-roof tank at the Mt. Pleasant refinery. Some loss of anti-icing additive in the tank bottom was usually noted. Apparently there was no filtration or drying of the fuel in the refinery. However, the anti-icing additive was stored in a tank vented through an alumina dryer. From the refinery the JP-4 was shipped some 135 miles by private pipeline to the Petrofina terminal in Grapevine, Texas, which was equipped with two 20,000-bbl floating-roof tanks in JP-4 service. The incoming JP-4 was routed through a screen and a nominal 5-micron filter on its way to these tanks. The tanks were said to have closed roof drains with flex lines. The fuel fill and discharge lines were about one foot off the tank bottom. The tank bottoms were said to be dished, with the water drain line extending to the low point. It was stated that water was drained off every day or two; however, at the time of the survey, the drain line on one of the tanks had been dirt-banked, presumably to prevent freezing. These tanks supplied fuel directly to the truck loading rack without any intermediate filtration.

d. Petroleum Refining Co.

This JP-4 represented straight-run cuts from "sweet green crude" (not gas-well condensate) and consisted of a mixture of kerosine, VM & P naphtha, and other refinery stocks as available. The stocks were copper chloride sweetened if necessary. No additives (other than anti-icing) were being used. Salt-box driers were being used both in the fuel line leading to the blending tank and on the vent line of the anti-icing additive storage tank. The anti-icing additive was blended into the fuel while circulating the contents of one of the blending tanks. Ordinarily the JP-4 fuel was not filtered except through 100-mesh screens. However, there was a felt filter that could be used to filter fuel to the truck loading rack in the event of excessive dirt in the blending tanks.

3. Carswell Facilities and Procedures

a. General

Carswell's bulk storage area included two floating-roof tanks and four smaller fixed-roof tanks, tank car and tank truck unloading facilities, and a truck fill stand. The hydrant system included five operating storage areas, all originally Panero with two of them converted to Pritchard. The only hose carts available for the Pritchard systems were four MV-2's. The refueling vehicles included F-6's, R-2's, and one F-7.

b. Bulk Storage and Receiving Area

Carswell facilities included two 20,000-bbl floating-roof tanks (Nos. 4A and 4B) and four 4,500-bbl fixed-roof tanks (Nos. 1, 2, 3, and 4). The fixed-roof tanks were used for reserve storage and were rotated every 20 to 40 days. These reserve tanks were said to show very little if any water, and these were gaged as "zero" water each day during the survey. The drain lines of these reserve tanks went in through the bottoms, and it was not clear whether or not they were flush or extended up into the fuel. In any case, little or no water could be obtained through these drains. The reason for this absence of water was not clear.

The two floating-roof tanks were equipped with closed center roof drains through a flex line to a foot valve that was normally open. The internal configuration of these tanks was not known with certainty, as the drawings on file did not agree with statements of Civil Engineering Maintenance personnel who had cleaned Tank 4B in 1962. So far as could be ascertained, Tank 4B was originally installed in 1953 with a 3" crown to the center, and apparently a sump for the water drain line was installed in 1958. This sump was about 24" in diameter and 12" deep, but there were no records on its location. Tank 4A was originally installed with flat bottom in 1951. It was thought that possibly a sump might have been added. Both tanks had an 8" pipe connection with centerline 13" above the tank bottom, serving as outlet line in Tank 4A and as common inlet-outlet in Tank 4B. The inlet in Tank 4A was a 6" line. It was thought that these lines had closed ends and slotted sides, but this did not show on the drawings.

Whatever the internal configuration, it was definitely known that the water level at the gaging hatches could not be kept down much below one to two inches and that the water gage readings were definitely related to rainfall, as illustrated in Figure 1. The gage readings shown in this graph were those taken each morning, presumably before water draining was accomplished. Although the correlation is by no means exact, the relationship is unmistakable. Further evidence of the major role of entrance of rain water was found in follow-up data taken in April 1963, over a weekend on which four to six inches of rain fell in this area. The tank gage readings were:

	Tank 4A	Tank 4B
Friday	7/8"	3/4"
Monday	1-1/2"	1-1/8"
Tuesday	1 "	1-1/8"

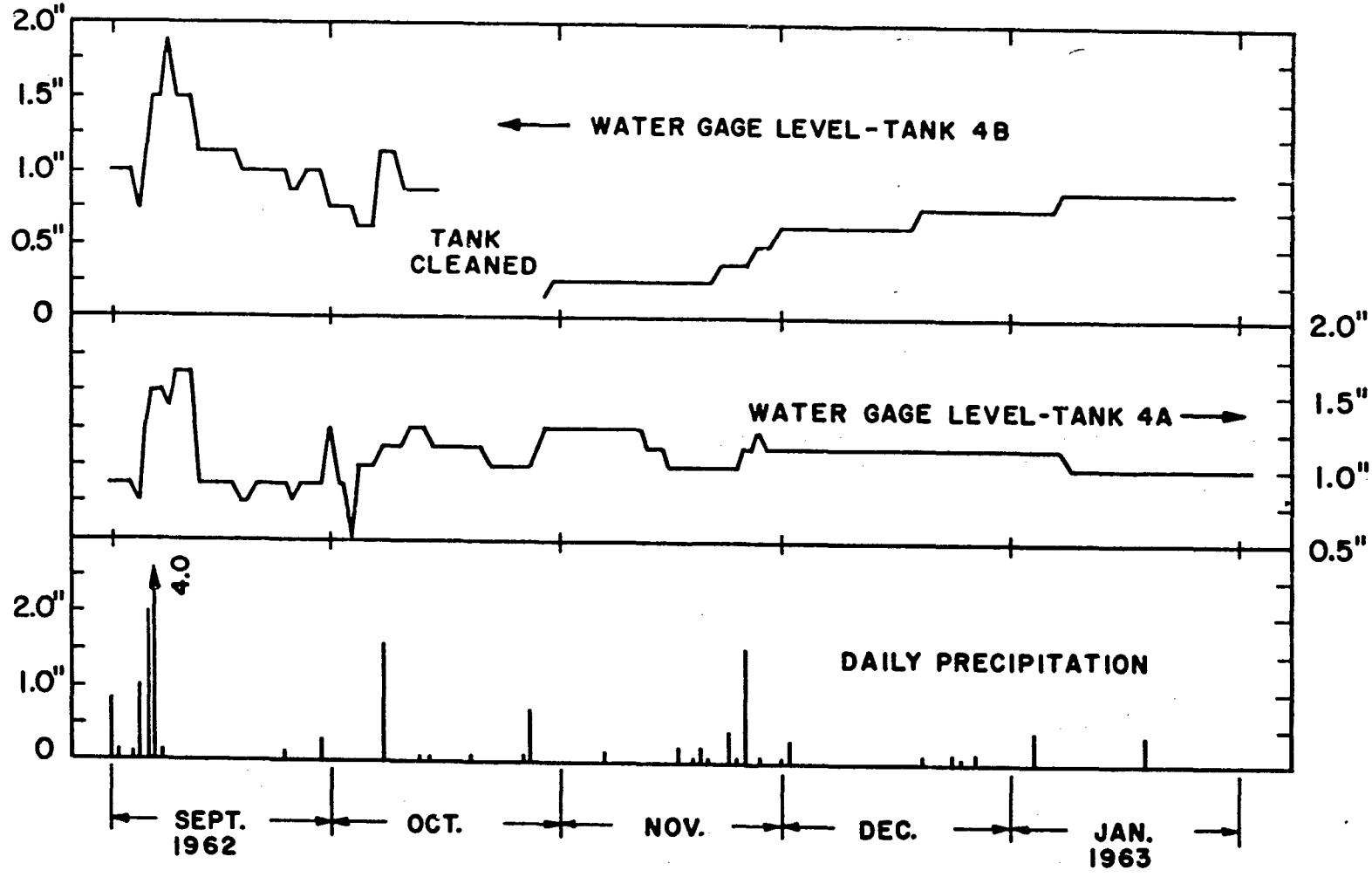


FIGURE 1. WATER IN BULK STORAGE TANKS AT CARSWELL AFB

The increase in gage reading from Friday to Monday probably does not reflect the total amount of water entering the tanks, since water was very likely drawn off during the weekend. The content of anti-icing additive (methoxy-ethanol) in these tanks decreased from 23-24% on Friday to 10% on the following Tuesday, indicating more than a 100% dilution with rain water. Thus, it appears that the metal-to-metal roof seals on these tanks admitted major amounts of water during heavy rainfall periods.

Tanks 4A and 4B had been inspected in October 1962, and Tank 4B was cleaned at that time. Tanks 1, 2, 3, and 4 had gone about four years without inspection when they were inspected in 1962.

The pumps used to unload tank cars and tank trucks into the bulk storage also supplied fuel to the truck fill stand in this area. This fuel could come either from the bulk tanks or directly from tank cars or tank trucks that might be unloading at the time. There was no filter-separator in the line to the truck fill stand, although one was scheduled for installation.

A separate pumphouse at the bulk tanks served to transfer fuel to the operating storage areas; such transfers could be performed whether or not unloading operations were in process. Gravity transfer to the operating areas was impossible because of the difference in elevation.

It was attempted to alternate Tanks 4A and 4B each day, i.e., unload into one tank and issue from the other on one day, then reverse the next day. However, the demands of scheduling sometimes required that the tanks be "turned around" without any settling time at all. Although the tank scheduling was not followed in detail, it appeared that the most severe disruption of the idealized schedule would occur during or immediately after a weekend, since no fuel would be received on Saturday or Sunday.

Incoming fuel shipments were checked visually by taking top dip samples; this was performed regularly on tank trucks, but there was some question in the case of tank cars. In addition, one dip sample per day was taken from a tank car or tank truck for laboratory analysis. One sample per week was taken from each bulk storage tank for laboratory analysis. This latter sampling seemed to be a local procedure, as it is not required by the manuals or T.O.'s. These samples were taken by thief sampler about six or eight feet down into the fuel. The water bottoms of the floating-roof tanks were sampled every month for sulfide test.

It was observed that the strainers in the fill plugs of the unloading racks were checked and cleaned regularly before connecting up each tank truck or tank car. Cleaning consisted simply of knocking out the

debris. No excessive amounts of debris were observed. It was verified that these strainers were 80 mesh rather than the 30-40 mesh that is required. At one time, 100-mesh strainers had been used as extra insurance, but these were found to be too readily plugged. The basket strainers in the unloading lines, which were 100 mesh instead of the required 80 mesh, were cleaned weekly.

Bulk fuel temperature was running between 46 and 50°F during the survey.

c. Operating Storage Areas

The five operating storage areas were all installed as Panero-system, but Areas A and C had been converted to Pritchard. Of the three remaining Panero areas (B, D, and E), Area E was in the alert area and was not available for examination or sampling. The tank and pumphouse facilities were almost identical for all five areas. Each had six 25,000-gallon underground tanks with conventional 300-gpm deep-well pumps at one end. Contradictory information was obtained as to whether the tanks were originally installed level or pitched toward one end. The tank fill lines were said to have been converted to a closed-end configuration with slotted sides. The gaging hatch on each tank was at the opposite end from the pump. There was some doubt as to whether or not the gaging pipes extended all the way to the bottoms of the tanks. The filter-separators in these areas will be discussed in a following section.

One tank in each area was reserved for defuel only. The defuel might be either transferred to one of the other tanks or issued directly to aircraft. On rare occasions, it might be necessary to transfer some defuel back to bulk storage.

The operating storage tanks were being inspected on a three-year schedule.

Water gaging of each tank was performed every morning, and any excess water was pumped off. It was confirmed by gage records that most of these tanks did not show any water and that water removal was rarely necessary. During the survey, only Tanks D-3 and D-6 were showing water. Several months previously, Tanks C-2, C-3, and D-1 were the most frequent to show water. The gage amount was usually less than 1/4", rarely as much as 1/2".

The three Panero areas (B, D, and E) each included three filter-meter pits with Warner-Lewis micronic filter Model HPD-600AN. The

two Pritchard areas were connected up to a total of five laterals and ten outlets.

d. Aircraft Fueling and Defueling Operations

Because of security restrictions, no fueling or defueling operations were witnessed directly, so this information is based solely on the comments of Carswell personnel.

At the time of the survey, the single-point refueling nozzles had not yet been equipped with sampling cocks. The refueling samples for visual or laboratory examination were drawn either at sampling cocks on the hose carts or micronic filters, or by disconnecting the nozzle to catch a sample. This latter method is somewhat undesirable in that the sample does not represent full flow.

The parking arrangement of the B-58's was such that, when using the Panero system, some 110 feet of hose had to be used. This was considered to be somewhat of a hazard and an operating disadvantage; therefore, much of the refueling and defueling of B-58's was performed by refueling vehicles.

e. Aircraft Sump Draining and Sampling

Since the Fuels Supply personnel at Carswell were not permitted access to the aircraft to obtain sump drain samples, this function was performed by servicing personnel of the 43d and 7th Support Groups (B-58's and B-52's, respectively). The information in this section was obtained from these groups and from General Dynamics - Fort Worth.

The B-58 does not have separate body and wing tanks, but rather two main tanks (forward and aft) and a reservoir tank and a balance tank. The tanks are flat-bottomed and do not have sumps. A total of 14 drain points are provided with special fittings. In some cases special cartridges containing dichromate had been inserted in these fittings as an experimental biocide and anticorrosion agent. The reservoir tank, which is used as emergency fuel supply, tends to accumulate all of the trash from the whole fuel system. This reservoir tank has a single drain at the rear, extending down through a flexible hose to where it can be reached from beneath the aircraft. There had been one instance of in-flight freezing and rupture of this line with loss of fuel, so extra care was observed in checking this drain point. The servicing group scheduled regular checks on all drains in accordance with the applicable T.O.'s. In addition, they drew one sample per day for the laboratory. This was said to represent initial draining - i.e., there was no predrain before sampling. However, the regular servicing checks and

draining could have been performed prior to the laboratory sampling. The laboratory samples were said to be taken usually from an inboard drain on the left side of the aircraft. There had been only three cases of suspect samples, and in each case the rechecks on fresh drain samples showed good fuel.

Personnel from the 7th Support Group indicated that the B-52F's had some 26 drain points, and it was not feasible to take "composite" drain samples for laboratory analysis (as is indicated in SACM 67-2 and elsewhere). The regular maintenance check and draining is performed only once per mission, within eight hours of takeoff. For aircraft on alert status, daily sump draining is required, even though the alert status might last for as much as 28 days. This was felt to be unwarranted, since water was never found after the third or fourth day. It was said that the only drain points showing much water were the outboard wing tanks. Ordinarily each drain point is checked by drawing 1/2 gallon into a clear jar and repeating as needed to obtain clear fuel. Servicing group personnel tended to minimize the importance or danger of the small amounts of water that they had encountered and felt that the current procedures were more than adequate to prevent trouble. In case a sample was to be taken for laboratory analysis, this would immediately follow the regular sump drain. The laboratory personnel stated that they did not get B-52 samples each day as required by SACM 67-2 and that the actual frequency was more like once a week.

f. Mobile Servicing Equipment

As mentioned previously, four MV-2's represented the only hose carts available for use with the Pritchard systems, and this sometimes represented a problem. Two more MV-2's were scheduled for service at Carswell. They were authorized MH-2's but no longer had any. The refuelers included ten F-6, one F-7, and four R-2 units in JP-4 service.

Operating difficulties that were reported were the same as at Bergstrom: filter-separator door leakage on the MV-2's and hose reel damage on the R-2's. No trouble was reported at Carswell with the Thermoline interior tank coating.

g. Filter-Separators

All of the fixed filter-separators in the operating storage pumphouses were horizontal units converted from the old "hay-pack" units, listed as Warner-Lewis Type M-397P Model FC-5E3 (300 gpm) with CC-E-3 cartridges. The nameplates called for element change at 12 psi differential pressure. The filter-separators were equipped with 0-30 psi differential pressure gages at the time the conversion was made. All of the gages that

were observed appeared to be in excellent operating condition, and it was evident from manipulating the valves in the connecting lines that the gages were very well protected against overpressure. Subsequent correspondence with the manufacturer of these gages indicated that they had worked with SAC in the early stages of developing this particular application. Carswell fuels and maintenance personnel indicated that no operating troubles had been encountered in the use of these gages and that a great deal of reliance was placed on the gage readings in determining whether elements should be changed. Normal reading for new elements was 1 to 1.5 psi; most of those observed were reading 2 to 5 psi under flow conditions (12 psi was the change-out limit). This excellent performance of these particular gages is of particular interest when compared with the extremely poor performance of the gages of another manufacturer at Bergstrom.

The micronic filters in the Panero filter-meter pits were Warner-Lewis "Excello" Model HPD-600AN. These were also equipped with differential pressure gages.

Carswell criteria for element change in the fixed filter-separators were 18 months or 12 psi; in the micronic filters, 18 months, 10 psi, or 2,000,000 gallons. The pressure-differential criteria are manufacturer's nameplate recommendations in each case. Although T.O. 37A9-1-506 requires element change at 2,500,000 gallons in the case of "conversion-job" filter-separators, this criterion is ignored by Carswell, as elsewhere. Since there are no meters in the standard hydrant system to record gallonage, it is considered that there is no practical way to compute gallonage through these filter-separators.

At the time the anti-icing additive was first introduced, there were instances of premature buildup of pressure differential on the filter-separators. At the same time, the Panero micronic filter elements were observed to be stained brown on the effluent side (outside) but were relatively clean on the influent side (inside); in these units, there was not any excessive pressure buildup. These problems were traced back to the presence of excess glycerin in the fuel and/or water bottoms.

The R-2 refuelers at Carswell were all CDEC units with Briggs BFS-15-V-600 filter-separator. The nameplates on these units give curves of maximum and minimum pressure drops as a function of flow rate. Carswell was observing the then applicable T.O. requirements of 15 psi or 12 months as the criteria of element change.

In the case of the F-6 refuelers, the T.O. criteria of 15 psi, 18 months, or 5,000,000 gallons were observed, but it was indicated

that the allowable gallonage was never reached before pressure drop or (more usually) time limit required element change.

The Permadry 520-42 filter-separators on the MV-2 hose carts have an automatic shutoff when the pressure differential reaches 10 psi. This was the only criterion applied at Carswell, and this is technically correct, as the applicable T.O.'s do not specify a time or gallonage limit. It was mentioned that they had throughputs of up to five or seven million gallons without element change and that they would backwash if necessary to extend element life still further. They regarded this unit as essentially a permanent filter; this opinion (although incorrect) was reinforced by the lack of any time or gallonage criteria in the T.O.'s and the name of the manufacturer, Permanent Filter Corporation.

h. Laboratory Control and Sampling

Carswell's fuel laboratory, which had been operating about two years at the time of the survey, was equipped for KF-3 water analyses and Millipore solids determinations, as well as sulfide tests on water bottoms and dissolved solids in demineralized water. They were also being equipped to run anti-icing additive determinations and to use the Millipore field monitor kits for refueling samples. The frequency of sampling was essentially as specified in SACM 67-2 except that they were not able to sample each filter system every day it was used; a minimum rate of one sample per week was maintained. The laboratory was going to three-shift operation to step up the sampling and analysis rate.

As mentioned previously, samples were taken daily by top dip from one tank truck or tank car and weekly from each bulk tank (this latter a local practice). Water bottoms from bulk tanks are checked monthly for sulfides.

Since sampling cocks had not yet been installed on the single-point nozzles, sampling created quite a problem. The Panero refueling operations could be sampled after the micronic filters, and the Pritchard operations by a sampling cock on the MV-2 units, but neither of these would really represent "entering-the-aircraft" samples. In the case of refueling vehicles, it was necessary to disconnect the nozzle to obtain a sample. In view of these sampling difficulties, it was not the practice to run a visual check on each refueling operation; for the moment, they were aiming at one sample per day from each filter system for visual examination and laboratory analysis. So far as could be determined, no check was made on defuel quality before it was returned to the storage tanks.

The Carswell laboratory was keeping very excellent records on the solids determinations, with a running log on each filter system. This is apparently not required by standard procedures but was an innovation of one of the laboratory technicians. The trends were rather difficult to pick out in the case of the MV-2 hose carts, as there seemed to be a random variation that obscured most long-term trends. Also, the MV-2 units were often out of service for maintenance or repairs, which tended to complicate the records. The laboratory was also hoping to be able to set up records on differential pressure readings. At the time of the survey, these did not appear to be kept in any form that would be useful for controlling the operation closely.

Carswell laboratory personnel felt that they did not get representative or meaningful samples from aircraft sump drains, as they were not permitted to collect these samples themselves. Also, in the case of the B-52's, the frequency of sampling was much less than the nominal requirement.

The laboratory personnel placed heavy emphasis on the value of Millipore solids determinations in following the performance of a filter system. However, they had little or no confidence in the significance of Karl Fischer water determinations and were simply running these tests because of regulations.

i. Local Operating Procedures

The supplementary local instructions at Carswell AFB consisted of a series of "Petroleum SOP's" issued by former Base Fuels Officers and a series of "Lab SOP's" written by the laboratory personnel and signed by the current Base Fuels Officer. The Petroleum SOP's were somewhat out of date. The Lab SOP's deal mostly with internal laboratory operation and with the frequency, location, and methods of sampling. In general, the criteria for sampling follow SACM 67-2. One local addition is the weekly sampling of fuel in each bulk storage tank; a schedule is provided to spread these samples out through the week (Lab SOP #4). The Lab SOP's give a sampling schedule and specify who is responsible for the sampling of mobile refueling (Lab SOP #2), hydrant systems (Lab SOP #3), and aircraft sump drains (Lab SOP's #5 and #6). All persons taking samples are cautioned to use bottles supplied by the laboratory, to rinse with the fuel being sampled, and not to fill within less than one inch of the top. Procedures are given for reporting suspected fuel contamination and taking action.

4. Carswell Survey Sampling and Analysis

The Carswell sampling program was similar to that at Bergstrom except that more emphasis was placed on operating storage samples and that better sampling equipment and techniques were available in the Carswell survey. Tank samples were withdrawn directly into sterile one-quart sample bottles by means of a sampling device developed at SwRI. The samples were drawn by a hand-operated vacuum pump through aluminum or polyethylene tubing dropped to the desired level in the tank. This sampling apparatus, with a weighted flexible polyethylene tube, is shown in Figure 2. In operation, the weight is lowered to the desired level in a tank; the end of the tube may be positioned either on the bottom or a few inches off the bottom by means of the adjustable legs on the weight. When vacuum is applied, fuel moves up the tube and into the sample bottle. The small jar attached to the pump acts as a trap and flow control; the vent line of this jar is held closed while drawing the sample, and opened to stop flow instantly. Connections are made with rubber stoppers and rubber and copper tubing. The particular weight shown in Figure 1 is steel, weighs about 9 lb, and will pass through a 4-inch gaging hatch. Other later models have been made of brass or plated steel in various sizes. Each is equipped with a ferruled fitting for attaching and positioning the tubing.

In using this apparatus in the Carswell system, all components contacting the fuel were presterilized. However, it was necessary to use a given piece of tubing for several samplings, and it proved impractical to field-sterilize this tubing under existing conditions. Therefore, the sampling lines were simply rinsed thoroughly with solvents and then with the next test fuel (or water) sample prior to the actual sample draw. This procedure cut cross-contamination to a minimum but was not completely rigorous.

The Carswell sampling and analytical data are given in Tables 11-19. Laboratory test procedures are described in Appendix A.

a. Incoming Fuel Samples

Incoming tank trucks were sampled by top dipping and by drawing material from the manifold or other drain arrangement. Incoming tank cars were sampled by top dipping and bottom sampling through the hatch with the vacuum pump. The data in Table 11 indicated that there were no gross amounts of either solids or water in any of the samples, and in particular the bottom samples appeared unusually free of water. Both the top and bottom samples from one Premier tank car had solids contents well below the SAC maximum of 8 mg/gal for fuel serviced to aircraft.

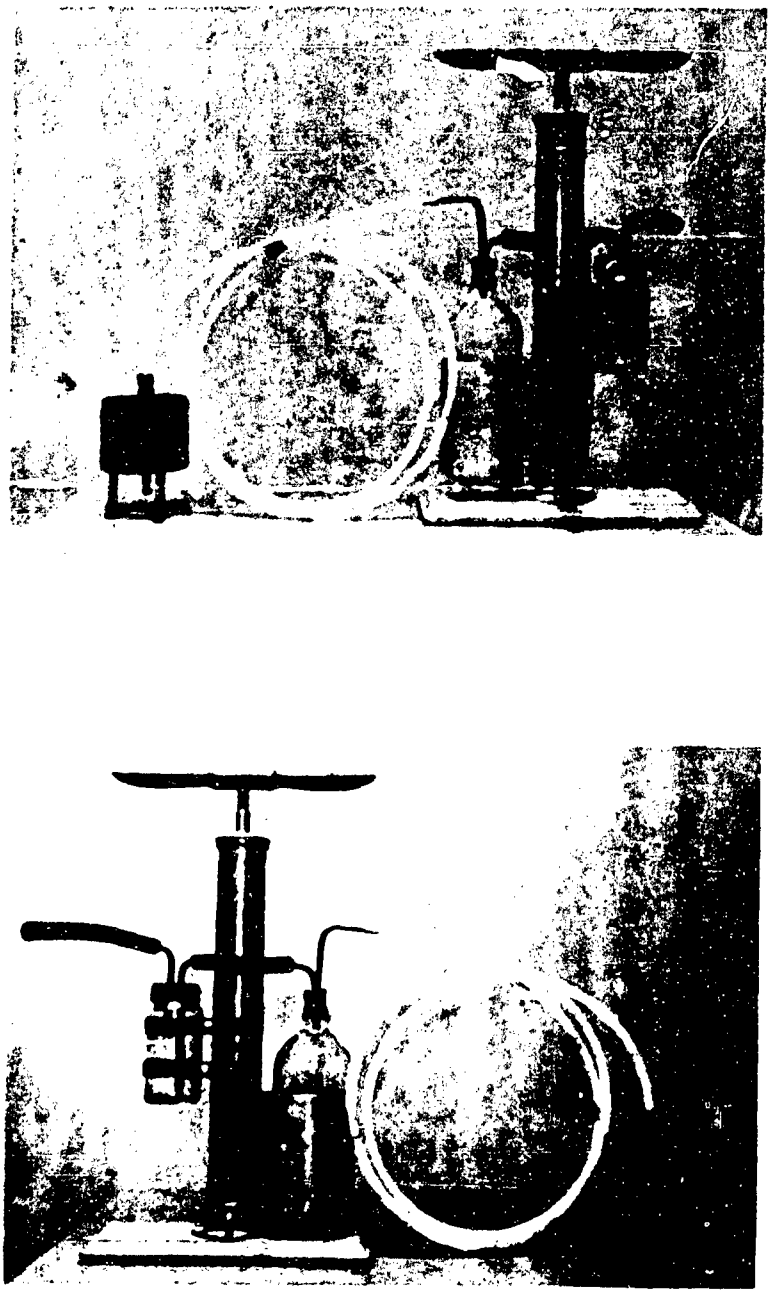


FIGURE 2. SwRI TANK SAMPLER

TABLE 11. INCOMING TANK CARS AND TRUCK SAMPLES AT CARSWELL AFB

Sample No.*	Supplier and Carrier**	Top or Bottom	Millipore Solids, mg/gal	Visual Observations on Settled Samples
101	Premier/A	Bottom	-	Moderate amount of fine particles
102	Same	Top	-	Moderate amount of lint
105	Petrofina/B	Bottom	-	Trash on bottom (rust, possibly water)
106	Same	Top	-	Few pieces trash, possibly trace water
109	Premier/A	Bottom	-	4 fair-sized rust particles, small amount of trash, possibly trace of water
110	Same	Top	-	Moderate amount of lint
111	Petrofina/C	Bottom	-	Very few small particles
112	Petrofina/B	Bottom	-	Few solid particles on bottom, some trash
113	Same	Top	-	Small amount of trash
125	Petr Ref/D	Bottom	-	Rust particles, large and small
126	Same	Top	-	Quite a few large fibers, numerous other particles
129	Premier/TC	Bottom	-	3 fairly large greenish-blue particles; some lint and other particles***
130	Premier/TC	Top	-	Numerous particles
131	Premier/TC	Bottom	2.2	Trace of trash on bottom, few particles dispersed
132	Premier/TC	Top	1.3	Moderate amount of trash (lint observed when drawn)

*Samples are listed in order drawn. Samples 101-113 were drawn on 4 February 1963, and Samples 125-132 were drawn on 5 February 1963. All samples were taken in clean, sterile one-quart bottles. Tank truck samples were taken by dipping or draining; tank car samples were taken by dipping or by vacuum-pumping from bottom through hatch.

**Identification of carriers: A) Mississippi-Red River; B) Associated Transport; C) Western Transport; D) Petroleum Refining Co. (own trucks); TC) Government-owned tank car.

***Fuel sample No. 129 was cultured for fungus count (Sabouraud's). A zero count was obtained.

TABLE 12. WATER SEPAROMETER TESTS ON CARSWELL AFB FUELS

Sample No.	Source	WSI*
103-104	Premier, Mississippi-Red River truck, top dip	98
107-108	Petrofina, Assoc. Transport truck, top dip	92
123-124	Truck fill stand No. 5, after drawing 4000 gal from Tank 4A, one hour after last truck of day had been unloaded into Tank 4A	98
127-128	Petroleum Refining truck, top dip	98

*Water separation index (WSI) was determined on a standard CRC water separometer, using the current standard Method 3255-T of FTS-791a.

TABLE 13. BULK FUEL STORAGE SAMPLES FROM CARSWELL AFB

Sample No.*	Source	Millipore Solids, mg/gal	Visual Observations on Settled Samples
114	Tank 4A, 12" from bottom (while trucks were unloading into tank)	0.0	Few small particles, unidentified
115	Same, 16' from bottom	1.9	Moderate amount of lint, trace of water
122	Truck fill stand No. 5, taken after drawing 4000 gallons from Tank 4A one hour after last truck of day had been unloaded into Tank 4A	1.4	Few fibers and other particles

*All samples were taken on same day (4 February 1963). Tank 4A had not received fuel over the weekend, but was receiving fuel all this day (Monday). All samples were taken in clean, sterile one-quart bottles. The samples from the tank were drawn directly into the bottles by use of a hand vacuum pump and polyethylene tubing. The truck fill stand sample was taken directly into the bottle.

TABLE 14. BULK STORAGE WATER BOTTOMS FROM CARSWELL AFB

Sample No.*	Date	Source	Visual Observations on Settled Samples
116	4 Feb 63	Tank 4B, interface	70% rusty yellow water, 30% fuel; some rust on bottom; little slime and rust at interface
117	4 Feb 63	Tank 4B, bottom	Almost all rusty yellow water (20 ml fuel); some rusty precipitate on bottom; interface almost clean
118	4 Feb 63	Tank 4B, water drain	70% orange, slightly cloudy water; brown sludge at interface and bottom
119	4 Feb 63	Tank 2, water drain	Mostly fuel, with about 10 ml rusty water on bottom and sides of bottle
120	4 Feb 63	Tank 3, water drain	Fuel with thin layer of rust on bottom; possibly some water; few large particles
121	4 Feb 63	Tank 4, water drain	Fuel with some dirty water on bottom and sides of bottle
133	5 Feb 63	Tank 1, water drain	Mostly fuel, with few ml of water and rust on bottom and sides of bottle
134	5 Feb 63	Tank 4A, bottom	Orange, slightly hazy water with about 20 ml fuel; interface almost clean
135	5 Feb 63	Tank 4A, interface	40% gold-colored water (almost clear); small amount of precipitate; small amount of sludge or emulsion at interface
136	5 Feb 63	Tank 4A, water drain	25% pink-gold, hazy water; no precipitate; interface has some yellowish slimy emulsion

*Bottom and interface samples were drawn directly into clean, sterile bottles through polyethylene tube and vacuum pump. Drain samples were taken directly into clean, sterile bottles.

Tank 4B, on 4 Feb 63, gaged 7/8" water. It was being used for issuing fuel, and had not received fuel for three days.

Tank 4A, on 5 Feb 63, gaged 1" water. It was being used for issuing fuel, and had received fuel on the previous day.

TABLE 15. ANALYSES AND COUNTS ON BULK STORAGE TANK BOTTOMS FROM CARSWELL AFB

Sample No.*	Water Layer Composition, wt %			Chloride in Water Layer, mg/liter	Total Count per ml in Water**	Fungus Counts (Sabouraud's) per ml			
						Water Layer		Fuel Layer	
	Glycerin	Methoxy-ethanol	Water			Fungi	Bacteria	Fungi	Bacteria
116	-	-	-	-	0	0	9	30***	9
117	1	32	67	-	0	0	16	-	-
118	-	-	-	-	0	15	3	5	2
119	-	-	-	-	2470	-	-	9***	2
121	-	-	-	-	-	-	-	0	0
134	<1	34	66	23	0	-	8	-	-
135	-	-	-	-	0	0	14	-	-
136	-	-	-	-	0	1	6	-	5

*See Table 14 for details on sampling locations and methods.
**Agar pour-plates.
***Yeast.

TABLE 16. OPERATING STORAGE TANK SAMPLES FROM CARSWELL AFB

Sample No.*	Source	Millipore Solids, mg/gal	Visual Observations on Settled Samples
141*	Tk C-6, bottom	2.7	Material on bottom; fibers and other debris in fuel
142	Tk D-6, bottom	-	15% cloudy orange water; some emulsion at interface
143	Tk D-3, bottom	-	90% cloudy orange water with dispersed solids and some precipitate; small amount of emulsion at interface
154*	Tk C-6, bottom, before defueling into tank (8000 gal on gage)	0.9	Some water on bottom; few rust particles on bottom; some lint
155	Same, 10 min after B-58 defueled 8000 gal into tank	0.0	Some lint; traces of water or fine particles
156	Same, 15 min after - sample from 3' off bottom	5.8	Water and rust on bottom
157	Tk A-4, 3' from bottom	30.8	Red rust on bottom; possibly water
158	Tk A-5, 3' from bottom	25.4	Layer of rust and probably water on bottom
159	Tk A-6, 3' from bottom	-	Red rust on bottom; possibly water
160	Tk A-3, 3' from bottom	21.6	White ppt and rust on bottom; probably water
161	Tk A-2, 3' from bottom	11.4	White ppt and rust on bottom; probably water
162	Tk A-1, 3' from bottom	13.4	White ppt and fair amount of trash or water; fuel pink
163	Tk A-1, 6' from bottom	20.6	White ppt, one fairly large rust particle, and some fibers; fuel pink
164*	Tk A-4, 3' from bottom (check on 157)	18.7	Red rust on bottom; possibly water
165	Tk C-6, bottom, before defueling into tank (4500 gal on gage)	0.0	Traces of material on bottom; some lint
166	Same, 2' from bottom	11.8	Lots of rust on bottom of bottle
167	Same, bottom, 5 min after defueling 9600 gal from B-58	0.5	Bottom of bottle fairly clean; some lint and few other particles

TABLE 16. OPERATING STORAGE TANK SAMPLES FROM CARSWELL AFB (Cont'd)

Sample No.*	Source	Millipore Solids, mg/gal	Visual Observations on Settled Samples
168	Same, 3' from bottom, 10 min after	9.7	Thin layer of rust on bottom of bottle; some lint
169	Tk D-6, bottom	-	7-10% gold-colored hazy water; small amount of slime at interface
170	Same, 1' from bottom	-	Water droplets on bottom and sides; fairly clean
171	Tk B-6, bottom	-	Water droplets on bottom (doubtful); fuel pink
172	Same, 1' from bottom	-	Water on bottom (more than 171); fuel pink

*Samples drawn through aluminum tubing by vacuum pump into clean, sterile bottle. Tubing was not cleaned between samples, but merely flushed with sample being taken. Samples indicated by asterisks were taken through new aluminum tubing.

TABLE 17. ANALYSES AND COUNTS ON OPERATING STORAGE BOTTOMS AND FUEL FROM CARSWELL AFB

Sample No.*	Water Layer Composition, wt %			Chloride in Water Layer, mg/liter	Total Count per ml in Water**	Fungus Counts (Sabouraud's) per ml			
						Water Layer		Fuel Layer	
	Glycerin	Methoxy-ethanol	Water			Fungi	Bacteria	Fungi	Bacteria
142	1	31	68	-	3	-	-	8***	0
143	1	27	72	-	0	1	11	-	-
161	-	-	-	-	-	-	-	-	8
165	-	-	-	-	-	-	-	0	0
169	-	-	-	92	0	12	3	11	3
170	-	-	-	-	-	-	-	11***	9

*See Table 16 for details on sampling location and methods.
**Agar pour-plates.
***Yeast.

TABLE 18. AIRCRAFT SUMP DRAIN SAMPLES FROM CARSWELL AFB

Sample No.*	Source	Visual Observations on Settled Samples
	5 February 1963	
137	B-58 No. 672, balance tank drain, 30 min after completing refueling	Few fibers, fairly large amount of fine particles
138	Same, reservoir tank, 35 min after	One bright orange crystal, several large brick-red and grey particles, fibers, numerous small particles, and possibly some water
139	Same, aft tank, 40 min after	Layer of fine trash on bottom
140	Same, forward tank, 45 min after	Layer of fine trash on bottom; some fibers
	6 February 1963	
150	B-58 No. 672, forward tank drain, after 4 hr flying time	Few fair-sized particles, quite a lot of small particles and lint
151	Same, aft tank drain	Many small particles, some lint, and some large particles
152	Same, reservoir tank drain	Small amount of rust on bottom, few large brick-red particles, few metallic particles, numerous fine particles
153	Same, balance tank drain	Amout 5-10 ml of slightly greenish water, some large particles of trash, and some brick-red particles
144	B-52 No. 041, outboard sump	About 5 ml of slightly yellowish water
145	Same, No. 1 main sump	Similar to 144, but slightly less water
146	Same, forward body sump	Similar to 144, but slightly less water
147	B-52 No. 049, forward body sump, 12 hr after refueling	Possibly 2 ml of water that seems to emulsify readily; 3 metal shavings and 3 red particles
148	Same, wing (main) sump	Some lint, 2 fair-sized pieces of trash; very little water on bottom
149	Same, left outboard sump	About 30-50 ml of tan-colored thick water; will not stir up or emulsify

*B-58 samples were taken in sterile 1-qt bottles, and B-52 samples in sterile gallon jugs (1/2 gallon samples). All of these samples were taken by aircraft servicing personnel.

TABLE 19. ANALYSES AND COUNTS ON AIRCRAFT SUMP DRAIN SAMPLES FROM CARSWELL AFB

Sample No.	144	149	153
Aircraft type	B-52	B-52	B-58
Location of drain	Outboard	Outboard	Balance tank
Water layer composition, wt %:			
Glycerin	1	1	2
Methoxyethanol	30	30	32
Water	69	69	66
Chloride in water layer, mg/liter	-	46	-
Total counts per ml water layer (agar method)	0	0	0
Fungus counts (Sabouraud's) per ml fuel			
Fungi	-	14 (yeast)	3
Bacteria	-	5	0

The CRC water separometer results (Table 12) indicated that the truck samples and one bulk storage sample (taken directly after truck unloading) had good water-separating characteristics.

b. Bulk Storage Samples

The bulk tank fuel samples (Table 13) were notable in that low-solids fuel was obtained from Tank 4A even at the time trucks were being unloaded into this tank. The sample taken from this tank through the truck fill stand, one hour after completing the day's receipts in this tank, indicated that good quality fuel can be dispensed in this system without an intervening filter-separator. Although it had been thought that the most unfavorable condition had been chosen, the bottoms in the bulk tank evidently had not been stirred up during the day's unloading operations.

The water bottoms samples from the floating roof tanks 4A and 4B (Table 14) were all somewhat similar in appearance, regardless of whether taken from the bottom, the interface, or through the drain line. The interface samples showed very little sludge or emulsion. The fixed-roof tanks (Nos. 1, 2, 3, and 4) gave drain-line samples consisting mostly of fuel.

The glycerin contents of the two water bottoms samples that were analyzed (Table 15) were 1% or less. The methoxyethanol content was 32-34%, i.e., considerably higher than at Bergstrom, as would be expected in view of the lower average temperatures at Carswell. The chloride content of only 23 mg/liter in the Carswell sample is well within the range of the average public water supply. The microbial counts on the Carswell bulk tank bottoms were all very low except Tank No. 2, which gave a count of 2470/ml Since this was the only water sample obtainable from the fixed-roof tanks, the condition of the other three tanks is unknown with respect to microbial growth. Water could very well exist in pockets in these tanks, inaccessible to the drain line. However, it is difficult to believe that the mere fact of relatively stagnant storage could favor microbial growth in this particular fuel-water system. In fact, in the light of later knowledge, it would appear that stagnant conditions should favor suppression of growth by the action of the anti-icing additive, especially if the amount of water was small.

Both of the Carswell floating-roof tanks showed appreciable microbial growth in a follow-up sampling on 26 April 1963, at which time the tank temperatures had been in the 77-80°F range for about a week. The following comparison was made on nutrient agar pour-plate counts (drain-line samples):

	Count per ml	
	Feb 63	Apr 63
Tank 4A	0	256
Tank 4B	0	3200

Although some renewed microbial activity was evident, the counts were still quite moderate.

c. Operating Storage Samples

The operating tank samples (Table 16) indicated the presence of appreciable amounts of water in Tanks D-3 and D-6, as predicted by water gage records. These tanks samples were all taken through the gaging hatches, and there is, of course, some question whether they were truly representative of the entire tank contents. It was not determined positively whether the gaging pipes extended to the bottoms of the tanks; if they did, then the samples would not be representative. The data on Tank C-6 before and after receiving defuel (Samples 154-156) would indicate that the bottom of the tank was far cleaner than a point three feet off the bottom. The same phenomenon was observed the next day (Samples 165-168). The series of samples from all six tanks in Area A (Nos. 157-163) showed excessive solid contamination and usually some water in samples drawn three feet off the bottom. If these samples are at all representative of the tank contents, it would appear that a heavy decontamination load was being put on the pumphouse filter-separators.

The two water bottoms that were analyzed (Table 17) showed methoxyethanol contents of 27-31%, or very slightly lower than the 32-34% in the bulk tanks. The chloride content of one sample of operating-tank bottoms was found to be 92 mg/liter. This was the highest observed at Carswell or Bergstrom, but not high enough to be any sure indication of sea water or brine contamination. The microbial counts on these operating-tank samples were all very low.

d. Refueling Line Samples

No refueling line samples were obtained at Carswell.

e. Aircraft Sump Drain Samples

The two series of drain samples (Table 18) were taken by Carswell servicing personnel. One of these series was from a single B-58, sampled shortly after refueling and again the next day after a four-hour flight. The samples after refueling showed a variety of fibers and other particles,

including one bright orange crystal (probably dichromate) and other large gray and brick-red particles, and also traces of water. The appearance of this sample is in line with comments of General Dynamics - Fort Worth that this tank tends to catch all of the trash in the system. The samples taken after flight showed somewhat the same pattern, except that the balance tank showed some water and some of the brick-red particles, and the reservoir tank showed some metallic particles.

The B-52 sump drain samples were taken from two aircraft. All samples showed free water; in each case the outboard sump samples had the most water. One of the B-52's gave only minor amounts of slightly yellowish water, but the other gave some 30-50 ml of dark, thick water bottoms and assorted trash.

The glycerin and methoxyethanol contents of the water bottoms from these aircraft were in line with those observed in the Carswell fuel handling system. Microbial counts were low, and the chloride content of the single sample tested was also low.

5. Summary of Carswell Operations

The fuel received at Carswell appeared to be of good quality, both as to contamination level and water separometer index.

The Carswell bulk storage capacity was apparently not adequate to permit overnight settling in all cases, or sometimes not even four hours' settling. The bulk tank sumps and drain line modifications were not shown in existing drawings, but it was evident that complete water removal could not be effected. Access of rain water through the roof seals was shown to be a major factor in increasing the gage levels and diluting the bottoms to a lower content of anti-icing additive. The water bottoms in the floating-roof tanks were quite clean and nearly sterile. Of the fixed-roof tanks, only one was found to have any water at all, and this one gave a microbial count on the order of a few thousand per milliliter. Other then this sample, relative freedom from microbial contamination was observed throughout the system and in aircraft sump drain samples; in fact, all samples other than this one fixed-roof tank gave counts not over 30/ml. The content of methoxyethanol was running about 27-34% throughout the system, which is in line with the equilibrium contents for the fuel temperatures involved.

The truck fill stand in the bulk storage area was not protected by any filter-separator, but still appeared to be furnishing good quality fuel under rather adverse conditions.

Sampling of operating tanks showed fairly high solids contents and some surprising reversals in the amount of solids at various depths. There was some question whether these samples, taken through the gaging hatches, were representative of the tank contents.

The differential pressure gages on the fixed filter-separators had given excellent service and were considered as a reliable indicator of the need for element change. However, it appeared that maximum use was not being made of these readings. In the case of the MV-2 hose cart filter-separators, Carswell had taken the technically correct position that the elements never required change except for excessive pressure drop; this situation certainly needs clarification in the existing T.O.'s. Mention was also made of backwashing the elements to restore performance; this appears to be poor practice.

The Carswell laboratory sampling schedule at the time of the survey was not yet up to the daily filter-system samples required by SACM 67-2. Sampling connections for the single-point nozzles were not yet available. The laboratory was keeping excellent records on Millipore solids determinations and felt that these have been of considerable value in following filter-separator performance. The Karl Fischer water determinations were not considered of much value. The laboratory was not receiving regular sump drain samples, particularly from the B-52's, and the lack of liaison between the laboratory and aircraft servicing groups appeared to represent a real problem in obtaining samples and interpreting the results. Fair amounts of "trash" and some water were found in the sump samples taken during the survey.

The general level of housekeeping and quality control was good, and there did not appear to be any problem with microbial contamination.

D. Kelly AFB

1. General

Intermittent visits were made to Kelly AFB in the early stages of the project to study their facilities and operations and to obtain information on the manuals, T.O.'s, and other documents pertaining to fuel handling. No organized sampling or survey program was performed.

Since Kelly's principal activity is maintenance and overhaul of aircraft, it is evident that defueling is an important part of their fuel operation, more so than in SAC operating bases. Aircraft are brought in to Kelly from worldwide locations, so it is logical to expect that a considerable amount and a wide variety of extraneous fuel will be defueled into their storage systems. No figures were obtained on the relative amounts of fresh

fuel and defuel in their system, but it was generally agreed that defuel represented a significant portion, possibly more than the fresh fuel consumption.

2. Fuel Supplies

Essentially all of the JP-4 at Kelly during the contract period from October 1962 through March 1963 was being supplied by Howell and Monarch, both located in San Antonio. The Howell fuel was discussed previously (under Bergstrom AFB). The Monarch fuel was quite similar in that it consisted of straight-run products from gas-well retrograde condensate and that no treating was required. The Monarch blend stocks passed through a 3' X 18' tower containing rock salt on the way to the blending tank. This tower picked up considerable moisture and could usually be drained for two or three minutes before fuel appeared at the drain line. The anti-icing additive was the only additive being used; this was blended with the fuel stocks by circulating the tank contents.

3. Kelly Facilities and Procedures

a. Fuel Storage Areas

Area 371 contained a Panero system with five 25,000-gallon underground tanks. Truck receipts were unloaded directly into the underground tanks, as was the case in all of the Kelly system. The tanks were originally installed with a pitch toward one end, and the gaging and water draw hatch was located at the low end. The pumphouse was equipped with a single 600-gpm Bowser filter-separator, No. 842DR600CL with 47B37 elements, cartridge-and-sock type. The nameplate data called for element change at 6 psi or one year. It was said that much of the refueling was performed with a single 300-gpm pump, so that the filter-separator would be operating at only half capacity. This area included a truck fill stand, equipped with another filter-separator. There was a single filter-meter pit, equipped with a Bowser No. 839-100 Stock 9510547 micronic filter with No. 88862 cartridges. This unit was labeled as a "filter-separator" on the case, although it was operating as a filter only.

Area 367 included a Pritchard-system pumphouse with four 50,000-gallon tanks. These were originally installed level, but water draw pipes were installed at each end to allow for shifting of the tank in either direction. The two 600-gpm filter-separators at this pumphouse were Bowser 842D CL, F-4, with A-1389-A cartridges; nameplate data called for element replacement at 15 psi or one year. As of late 1962, this system was operative for refueling but not defueling, as some control valve troubles

had been encountered. The hydrants in this system (two pits, four laterals) were almost a mile from the pumphouse, and it was stated that the 8" refueling line and the 6" defueling line had numerous bends, both horizontal and vertical. Startup of the system had accumulated a large amount of water in this system, and doubt was expressed that they had ever been able to remove it completely from these refueling and defueling lines. MH-2A hose carts were used in the refueling operations.

Area 960, with six 25,000-gallon underground tanks, served to supply refueling vehicles. The tanks had originally been installed with a pitch toward one end. The two filter-separators in this area were Bowser 842DR600CL units with 47B37 cartridges, to be changed at 6 psi or one year. A sample of the water bottoms from one of these tanks in December 1962 proved to be mostly glycerin, as discussed in one of the following sections. Trouble was being encountered with buildup of pressure drop across these filter-separators, and the elements were changed in April 1963. Records on one of the units showed that the elements were last changed in May 1961 and that a total of 14,456,670 gallons of fuel had been passed through the unit during the two years. When this filter-separator was opened up (April 1963), there was about one gallon of thick, sirupy material in the bottom of the housing and a layer of what appeared to be the same substance on the cartridges and socks. This material was readily water soluble and was hosed out. The diaphragm valve on the filter-separator fuel outlet line was also covered on the inside with this sirupy material. The other filter-separator, in which the elements had been changed four days previously, was found to contain about twenty gallons of water, apparently backed up into the inlet line during the fresh-water flushing operation when the elements were changed.

Area 930, which is adjacent to Area 960, contained one aboveground fixed-roof 5000-bbl tank, used as reserve storage for Area 960. There were no filter-separators nor any large transfer pumps in Area 930; the fuel is fed by gravity to the tanks in Area 960. The 3" water drain line in the aboveground tank, said to be flush with the flat tank bottom, yielded a mixture of fuel and rusty water. This tank handled only fresh fuel and was filled about once a month.

In defueling operations, fuel was dumped back into the underground operating tanks either from fueling vehicles or through the Panero pits. Pritchard defueling was not operational at the time. It was stated that salt water had been encountered in these tanks some time previously.

b. Mobile Servicing Equipment

The Kelly F-6 refuelers (Warner-Lewis filter-separators) apparently had given no serious problems, except for trouble with the Thermoline interior coating. Five of these units had to be cleaned and recoated within about three months of when the anti-icing additive began to be used in early 1962.

The R-2 refuelers at Kelly were equipped with Briggs BFS-15-V-600 filter-separators with A-1817 elements. The expendable external wool sock had given serious trouble with fiber shedding, which continued even after passage of a million gallons through the unit. Kelly personnel felt that this problem still had not been solved as of early 1964, but that fuel operating personnel had learned to live with the situation.

The MH-2A hose carts used at Kelly carry a Briggs BFS-11/10-V-600 filter-separator with A-1851 coalescers and A-1809 separators. This is not the filter-separator listed in the applicable T.O.'s.

After loading a refueling vehicle, it would be normal practice to hold for 20 minutes or more and then check and drain the water segregator and the filter-separators. However, this 20-minute period was regarded as optional and would be omitted or cut short if demanded by scheduling.

4. Samples Taken at Kelly

Samples were taken from an underground tank in Area 960 and from the aboveground tank in Area 930 during December 1962. These were drawn so as to accumulate the water bottoms, discarding fuel until the sample consisted mostly of water layer. Observations and test results on these samples were as follows:

	Area 960 (underground)	Area 930 (aboveground)
Appearance	Thick, brown, opaque, with about 3/16" of slimy cuff at interface	Cloudy, rusty water, with slight cuff at interface
Methoxyethanol, wt %	4	10
Glycerin, wt %	77	30
Chloride, mg/liter	480	Negative
Fungi isolated	Penicillium sp. Aspergillus niger Aspergillus flavus	Helminthosporium sp. Nigraspora sphaerica
Bacteria isolated	Gram-negative medium-size rods; rapid mucoid growth on Sabouraud's medium, poor growth on nutrient agar, sparse growth in broth	None

Although sampling was not performed under aseptic conditions, it is not considered likely that all of the above microorganisms were extraneous; i.e., it appears that the bottoms did contain viable microorganisms. The extremely high glycerin contents, in comparison with later observations of only 1-4% in the Bergstrom and Carswell bottoms, reflect the earlier data and smaller fuel consumption at Kelly. In December 1962 the suppliers were barely converted over to the 2% glycerin additive, and residues from the old 10% glycerin additive probably were present in their systems, as well in the Kelly system. In the case of the Area 960 tank, receipt of defuel also could have been a factor in the extremely high glycerin content. The high chloride content in the bottoms from this tank also pointed to heavy contamination from defuel. This content would correspond to about 2.5% sea water in the total bottoms sample, or 13% sea water in the "water" portion of the bottoms (excluding the glycerin and methoxyethanol).

5. Summary of Kelly Operations

The Kelly fuel handling is a small operation in comparison with that at SAC bases, but it has some interesting problems created by the receipt of defuel from worldwide bases. The possibility of contamination by sea water and microorganisms is especially great in the Panero tanks, where

defuel is dumped without any filtration whatever. Even in tanks used for refueling vehicle operations only, high concentrations of chloride were found. The high glycerin contents found in Kelly tank bottoms reflected the small volume of fuel handled and the then-recent changeover from the old high-glycerin additive.

IV. EXPERIMENTAL PROGRAM - TANK STORAGE TESTS

A. General

Following the inspection and analysis of samples from Bergstrom, Carswell and Kelly Air Force Bases, an experimental program was proposed and later approved, with revisions, by the Air Force project engineer. This program was directed primarily at studying the effects of anti-icing additive on microbial growth in storage tanks and in drums. The tank storage program, which is discussed in this section, also included attempts to evaluate stir-up of tank bottoms in transfer operations and settling rates after transfer.

B. Test Facility

The tank storage test facility consisted of two 4000-gallon underground steel tanks equipped with a centrifugal pump and suitable plumbing to permit transfer of fuel from tank to tank or circulation of fuel in either tank. The tank installation and plumbing layout are shown in Figure 3. The tanks were fabricated to order and were installed at the start of the program with a 6-inch slope toward one end; they shifted very little (less than one inch) during the program. Connections were provided for unloading fuel delivered by truck and for pumping to and from a filter-separator test facility that was available from a previous program. This latter facility was not used in the present program. Connections were provided to draw samples from the pump discharge line and to inject contaminants or additive into the pump suction line.

The suction and fill lines in each tank were end-capped and slotted as shown in Figure 4; the end caps normally rested on the bottom of the tanks. Pumping velocities in these 2-inch pipes were approximately 6 ft/sec, which is believed to be substantially higher than normal practice in field operations. Because of the position of the intake slots, 2 inches from the bottom near the high end of the tank, it was not possible to empty either tank completely during transfer operations; about 100-120 gallons would remain. Since this is approximately the amount of aqueous phase added to the two-tank system, it is evident that most of this aqueous phase would stay in whichever tank it was placed; i.e., subsequent fuel transfer operations from tank to tank would move only a small portion of the water out of its original location.

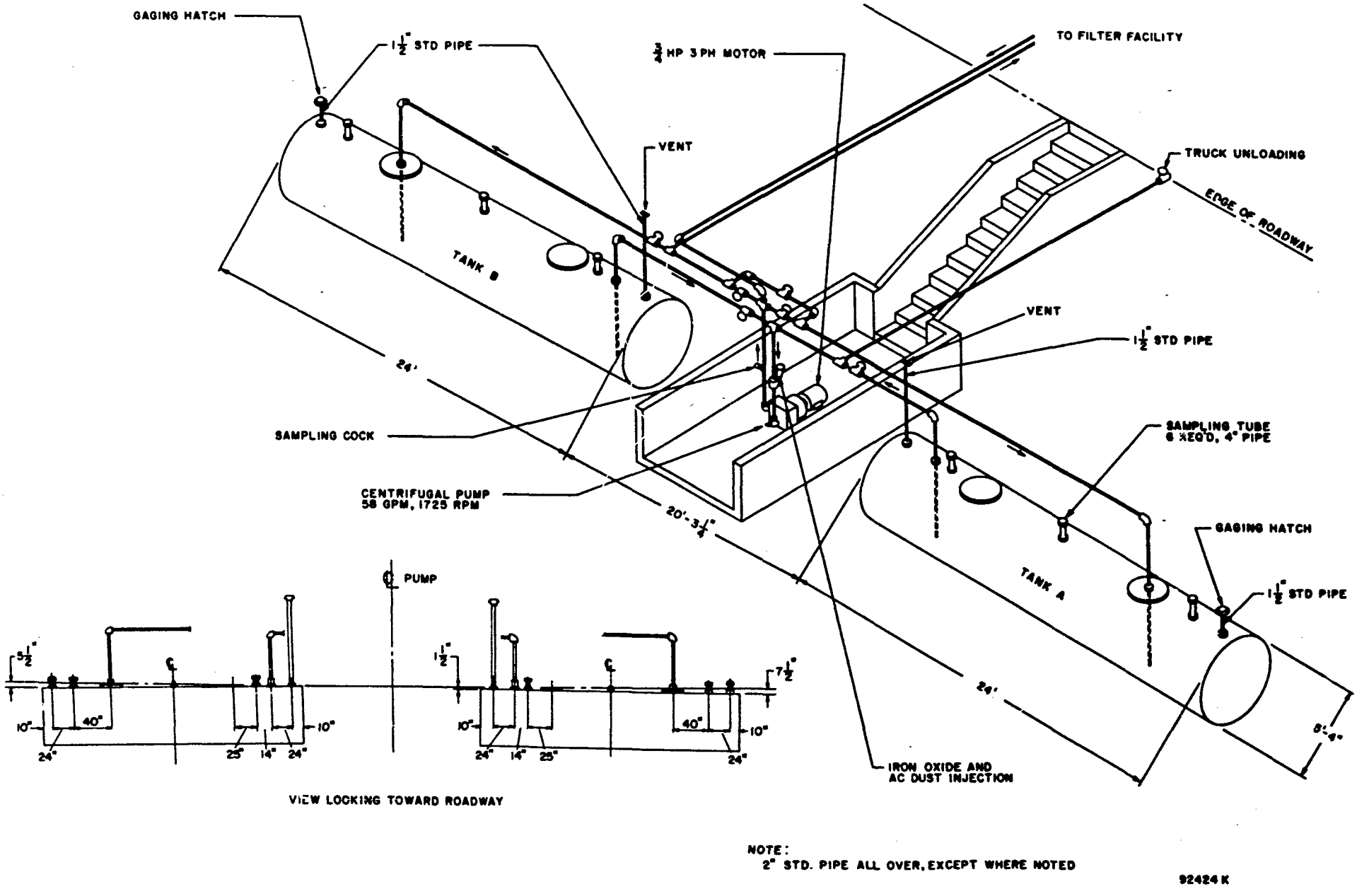


FIGURE 3. TANK INSTALLATION AND PLUMBING LAYOUT

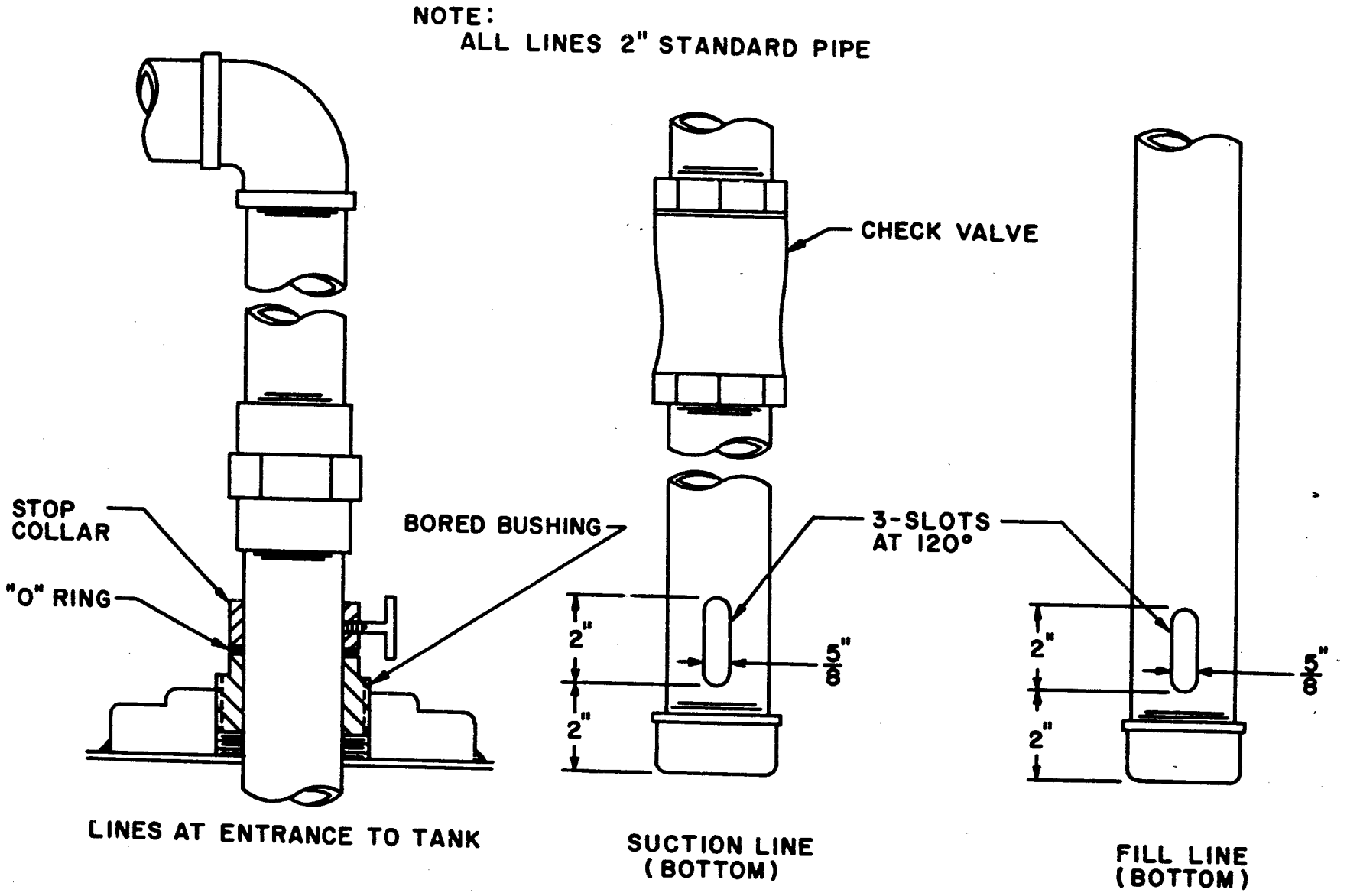


FIGURE 4. SUCTION AND FILL LINES CONFIGURATION

C. Test Materials

1. JP-4 Fuel

A truck shipment of 4265 gallons of JP-4 fuel without anti-icing additive was received from Humble Oil and Refining, Baytown, Texas, on 31 May 1963. This fuel was unloaded mostly into Tank A with the excess in Tank B. After two weeks, the fuel was transferred back and forth several times and then sampled (Tank B). The results of inspection tests on this sample are listed in comparison with the supplier's inspections in Table 20. The fuel showed considerable loss of light ends during this time, although this was not reflected in the API gravity. There was also an apparent increase in sulfur and mercaptan content that was unexplained. The fuel conformed to specification requirements except for the low vapor pressure after storage. Losses of light ends in storage would not be expected to affect the microbial-growth characteristics of the fuel.

2. Water Bottoms

The water bottoms originally added to the tanks was made up of approximately 94% fresh (tap) water, 5% natural sea water (Woods Hole), and 1% glycerin (USP), along with small amounts of microbial inoculant. This mixture was chosen to give a growth medium that is realistic in terms of field conditions. Toward the end of the storage period, the water bottoms of one tank was treated with methoxyethanol to a final concentration of 20%, the other ingredients decreasing correspondingly. The methoxyethanol was commercial material sold for anti-icing and general solvent use.

3. Contaminants

At various stages of storage, red iron oxide (Fisher I-116) and standard coarse AC dust were introduced into the system through the pump suction line. These were slurried with refined kerosine (Bayol D) for injection.

4. Microbial Inoculant Material

The inoculant material consisted of bacteria and fungi isolated by the University of Dayton (Table 21) plus raw cultures from Bergstrom AFB bulk storage.

Seventeen UD bacterial cultures were supplied in screw cap tubes, streaked on agar containing no added nutrients, covered with a nutrient solution composed of either sea water or Bushnell-Haas mineral salts medium, which in turn was covered with sterile JP-4 fuel. It was reported that these bacteria

TABLE 20. INSPECTION TESTS ON JP-4 FUEL FOR TANK STORAGE TESTS

	Supplier's Date*	SwRI Data**	Spec Limits
Distillation: IBP, °F	147	184	--
10%, °F	259	260	--
20%, °F	283	278	290 max
50%, °F	326	316	370 max
90%, °F	406	408	470 max
FBP, °F	446	464	--
Residue, %	1.0	1.1	1.5 max
Loss, %	1.0	0.4	1.5 max
Gravity, API	52.8	53.2	45.0-57.0
Existent gum, mg/100 ml	0.6	--	7 max
Potential gum, mg/100 ml	0.8	--	14 max
Sulfur, total, wt %	0.019	0.009	0.4 max
Mercaptan sulfur, wt %	0.0004	0.0014	0.001 max
Reid vapor pressure, psi	2.6	1.54	2.0-3.0
Freezing point, °F	-100	-76	-76 max
Aniline-gravity product	7550	7794	5250 min
Aromatics, vol %	7.7	7.6	25 max
Olefins, vol %	1.0	1.7	5 max
Smoke point, mm	30	--	--
Smoke volatility index	66.5	--	52.0 min
Copper strip corrosion	1-A	--	No. 1 max
Water separometer index (standard)	97***	99	--
(modified)	91***	78	--
Water reaction, interface rating	1	1	1-b max
volume change, ml	0	1	--
Thermal stability (300/400°F):			
Filter pressure drop, in. Hg	0.05	0.3	13 max
Preheater rating	1	1	Less than No. 3

*Contained Santolene C, 5 lb/1000 bbl; no anti-icing additive.
**After two weeks in tanks.
***SwRI data on sample dipped from truck.

TABLE 21. UNIVERSITY OF DAYTON STOCK CULTURES

No.	Microorganism	Isolated*	Media**
Bacteria			
UD-1	gpc	Fuel, water & tubercles	TSA, BH/fuel
UD-2	gpc	Tubercle	TSA, SW/fuel
UD-3	Bacillus sp	Water	TSA, SW/fuel
UD-4	gpr	Fuel & tubercle	TSA, BH/fuel
UD-5	gpr	Fuel & tubercle	TSA, BH/fuel
UD-6	gpr	Tubercle	TSA, BH/fuel
UD-7	gpr	Tubercle	TSA, SW/fuel
UD-8	Arthrobacter sp	Tubercle	TSA, SW/fuel
UD-9	gnc	Water & tubercle	TSA, BH/fuel
UD-10	gnr	Water & tubercle	TSA, SW/fuel
UD-11	gnr	Tubercle	TSA, BH/fuel
UD-12	gnr	Water & tubercle	TSA, SW/fuel
UD-13	gnr	Tubercle	TSA, SW/fuel
UD-14	gnr	Tubercle	TSA, SW/fuel
UD-15	Bacillus mycoides	Filter	TSA, SW/fuel
UD-16	Streptomyces marinus	Filter	TSA, BH/fuel
UD-18	Pseudomonas stutzeri	Water	TSA, BH/fuel
Fungi			
F-1	Aspergillus niger		Sab
F-2	Penicillium ochro-chloron		Sab
F-3	Aspergillus tamarii		Sab
F-4	Fusarium roseum		Sab
F-5	Fusarium moniliforme		Sab
F-6	Chaetomium globosum		Sab
F-7	Alternaria tenuis		Sab
F-8	Cladosporium resinae		Sab
F-9	Spicaria violacea		Sab

*UD reported that the microorganisms isolated from a filter were in the 5-ml sample of mixed water and fuel put through a membrane filter.

**UD reported difficulty in growing the bacteria in completely liquid medium.

Identification of media: BH - Bushnell-Haas agar
SW - sea water agar
TSA - trypticase soy agar
Sab - Sabouraud's dextrose agar

would not grow satisfactorily in the liquid system without the agar. In order to increase these stock cultures after receipt at SwRI, the bacteria were transferred to agar slants (water-washed agar) in large 1-inch test tubes. After streaking out the bacteria on the agar, about 2/3 of the slant was covered with either sterile sea water or Bushnell-Haas medium, as in the respective stock cultures, and this in turn was overlaid with a layer of filter-sterilized JP-4 fuel. Here, as in all of the inoculants, the JP-4 fuel used was taken from the test tanks. After preparing the slants, they were incubated 10 days at room temperature.

The nine UD fungus cultures were growing on Sabouraud's dextrose agar slants that had been overlaid with an unidentified aqueous medium, presumably Bushnell-Haas. These fungi were planted on Sabouraud's media and incubated until mycelial growth appeared; then each was transferred to a culture flask with Sabouraud's dextrose broth overlaid with JP-4 fuel and allowed to grow for 14 days at room temperature.

The Bergstrom AFB microbial culture was obtained from the water bottoms in one of the floating-roof tanks (B-14). The sample of water bottoms was drawn directly from the drain into a sterile bottle, brought back to the SwRI laboratories, and at once used to inoculate a system consisting of Sabouraud's agar/Bushnell-Haas/JP-4 (total microbial count on the water bottoms as drawn was 200/ml). This culture was then incubated and handled in the same manner as the UD cultures.

Prior to inoculating the storage tank, a composite was made of the UD bacteria and fungi and the Bergstrom raw culture. First, most of the JP-4 was removed from each by suction, and then the contents of each tube or flask was stirred to mix the growth with the respective nutrient media. Then the aqueous media were poured into three Erlenmeyer flasks - one each was used for sea water, Bushnell-Haas, and Sabouraud's broth. In cases where microbial growth had adhered firmly to solid media, this was dislodged by scraping and was added to the composite. Each of the three Erlenmyer flasks was then shaken thoroughly, adding three drops of Tween 80 to emulsify the traces of JP-4 remaining in the aqueous media. Finally, the three microbial suspensions were mixed together.

This final composite, which was used to inoculate the storage tanks, was assayed at 2,600,000 microorganisms per milliliter.

D. Test Program and Procedures

1. Tank Preconditioning

It had been necessary to buy new tanks for this program in order to obtain the desired connections. However, it was recognized that it would have been more desirable to have tanks with thoroughly rusted interior surfaces, which are more typical of the great majority of field installations. Therefore, the tanks were first filled with a salt-detergent mixture, each standing full for about a week and empty for a week or more. After thorough scrubdown and rinsing with fresh water, the tanks were dried with rags. Inspection showed that the salt treatment had caused red rust to form, but the mill scale was still present underneath. In later operations, it became apparent that mill scale was lossening progressively and collecting in strainers and in the bottoms.

It was considered impractical to sterilize these tanks. Therefore, the microbial population represented extraneous microorganisms as well as the inoculant.

2. Initial Fill

The materials first charged to the cleaned tanks were:

JP-4 fuel	4060 gal*
Tap water	115 gal
Natural sea water	6 gal (5% of water bottoms by volume)
Glycerin	10 lb (1% of water bottoms by weight)
Composite inoculant	605 ml

The tap water, sea water (presterilized), and glycerin were added to Tank A along with 200 gallons of JP-4 fuel and mixed by recirculation. The inoculant was added while recirculating. Some three days later, the balance of the JP-4 fuel was transferred to Tank A. The final water-fuel ratio was approximately 1/33.

3. Sampling Techniques

The sampling apparatus was the same vacuum pump system used in the sampling at Carswell AFB (see Fig. 2, p.50) except that the polyethylene tubing was replaced by soft aluminum, which can be heat-sterilized. All sample

*Original load of 4, 265 gallons less material withdrawn for drum tests and sampling.

bottles, stoppers, and tubing that came into contact with the samples were sterilized before each sampling by dry heat (3 hours at 240°F+) or autoclaving (15 minutes at 15 psig). A clean piece of sterile tubing was used for each tank sampling. Ordinarily the weight would be lowered until the end of the tubing was about 6 inches above the interface for drawing the fuel sample; then the weight would be lowered and the water sample drawn with the tube on the tank bottom. If an interface sample was to be taken, it would be drawn last.

In almost all cases, the microbiological assays were started within one hour after the respective samples were drawn.

4. Test Schedule

The experimental work covered a period of over slightly seven months in 1963. Table 22 gives a log of the operations.

E. Test Results and Discussion

The JP-4 fuel as received was clean except for a small number of fibers. Inspection data on this fuel were given in Table 20. Water separometer tests on samples dipped from the truck showed a standard WSI of 97 and a modified WSIM of 91. After filling Tank A and putting the excess of a few hundred gallons in Tank B, the fuel was left for two weeks and then transferred back and forth several times, ending with the bulk of the fuel in Tank B. Recheck inspection tests showed some loss of light ends and increase in sulfur content (Table 20). The relatively low WSIM value of 78 on this sample was rechecked; the low values are believed to be caused by sample container contamination, as none of the later WSIM values on the tank fuel were below 97.

After preparation of the inoculated water bottoms in Tank A on 19 July, the fuel was also transferred to Tank A, giving a calculated water-fuel ratio of approximately 1/33. Repeated transfers back and forth between the two tanks failed to give any appreciable stir-up of sludge, water, or particulate matter. Fuel samples drawn successively, some 2 to 15 minutes after pumping had ceased, from levels 1.5, 26, 50, and 6 inches above the interface failed to show any stir-up; all samples were clear and bright with only a few particles in suspension.

Further attempts to induce stir-up were made between 2 August and 29 August. A number of back-and-forth transfers were made, and on two occasions solid contaminants were injected into the pump suction line during a transfer. One such injection was made with 1/2 lb red iron oxide and 1/2 lb coarse AC dust slurried in 1 pint of refined kerosine, and the other injection with iron oxide and kerosine only. In each case, tank samples taken directly

TABLE 22. LOG OF TANK OPERATIONS

Date	Storage Time, Days	Incubation Time, Days	Remarks
15 Apr-30 May			Tank preconditioning period.
31 May	0		4265 gal JP-4 to fill Tank A with excess in B.
14 Jun	14		Pumped back and forth, ending in Tank B; sampled.
12 Jul	42		Took 200 gal JP-4 from Tank B for drum tests.
17 Jul	47		Completed tank burial. Added tap water and sea water to Tank A.
19 Jul	49	0	Added glycerin, inoculant, and 200 gal JP-4 to Tank A.
22 Jul*	52	3	Transferred remaining JP-4 from B to A.
23 Jul-	53	4	Pumped back and forth 16 times for stir-up tests.
1 Aug	62	13	Sampled Tank A (water and interface).
2 Aug-	63	14	Pumped back and forth 12 times and added AC dust
29 Aug	90	41	and red iron oxide for stir-up tests.
20 Sep	113	64	Sampled Tank A (fuel and water).
4 Oct	127	78	Sampled Tank A (fuel, water, and interface).
10 Oct	133	84	Sampled Tank A (fuel, water, and interface).
25 Oct*	148	99	Split fuel and water equally between A and B. Sampled both tanks (fuel and water). Added 126 lb methoxyethanol to Tank A.
28 Oct	151	102	Sampled both tanks (fuel and water).
4 Nov	158	109	Sampled both tanks (fuel and water).
11 Nov	165	116	Sampled both tanks (fuel and water).
18 Nov	172	123	Sampled both tanks (fuel, water, and interface).
22 Nov	176	127	Sampled both tanks (fuel, water, and interface).

*Major portion of fuel and water bottoms remained in Tank A from 22 July to 25 October, except during back-and-forth transfers.

after pumping had ceased showed no appreciable suspended matter. Thus, it appears that the tank fill line configuration was such that no appreciable stir-up occurred, even at the relatively high line velocity of 6 ft/sec. An alternate explanation is that the presence of relatively large amounts of water bottoms provided a "trap" for the solid particles. The final attempt at obtaining stir-up data was made by recirculating in one tank while injecting 1/2 lb of iron oxide (slurried in refined kerosine) into the pump suction. One hour after injection, with the pump running continuously, samples were taken from the sampling cock on the pump discharge line. These proved to contain relatively large amounts of iron oxide and some fibers and other debris. However, tank samples taken after pumping had ceased were much cleaner. This implies that the recirculation provided sufficient turbulence to keep at least some of the solid material suspended in the fuel, but that it fell out almost immediately when pumping was stopped.

The factor that was missing in all of these attempted stir-up tests was the presence of the accumulation of fine rust, fuel gums, surfactants, emulsion, and microbial debris that is present in base fuel system tanks after a few years of service. The combination of solids and surface-active substances favors suspension of material in the fuel.

The analytical data and microbiological assays on the tank samples are given in Tables 23 and 24. The first samples were drawn from Tank A on 1 August, after 13 days of incubation. The water bottom and interface counts were on the order of 100,000 per ml, representing a significant increase over the nominal starting concentration of 3,400 resulting from inoculation.

Sampling of Tank A for microbiological assay was resumed on 20 September, following the transfer and stir-up tests. This sampling showed zero count and negative test for fungi in the fuel layer, as was the case in all subsequent fuel samples.* The water layer gave a count of about 20,000 with positive indication of fungi.

The next samplings of Tank A were performed on 4 and 10 October to determine the effect of transfers and circulation on microbial counts. The initial samples on 4 October were taken after 14 days at rest. Then, after one back-and-forth transfer and 90 minutes of recirculating in Tank A, another set of samples was taken immediately after pumping had ceased. A similar set of experiments was performed on 10 October. The results of the two sets of tests were contradictory, as shown by the following approximate counts:

TABLE 23. TANK "A" TEST RESULTS

Date of Sampling: / Days of Incubation:	1 Aug 13	20 Sep 64	4 Oct 78	10 Oct 84	25 Oct 99	28 Oct 102	4 Nov 109	11 Nov 116	18 Nov 123	22 Nov 127
Total Count per ml										
Fuel		0		0	0*	20	0	0	0	0
Interface	105,000*		665,000 290,000*	56,000 547,000*					1	0
Water	116,000*	19,600**	32,500 467,000*	310,000 54,000*	57,000* 43,000***	0	0	0	30	3
Bacteria Identified										
Facultative anaerobes	+				+* +***	-	-	+	-	-
Sulfate reducers					-	-	-	-	-	-
Iron depositors								-	-	-
Fungi										
Fuel		-		-	-	-	-	-	-	-
Interface			3 3*	+					-	-
Water		+**	0 2*	+	-	-	-	-	-	-
Miscellaneous										
Fuel sampling temp, °F		86		85	81	80	76	75	74	75
IFT, dynes/cm										38.8
WSIM		98	97							
Solids, mg/liter										0.6
pH of water					5.3	5.2	5.1	5.1	5.0	5.0

*Samples drawn immediately after pumping

**Sampling tube flushed by drawing through water bottom and discarding before taking sample.

***Samples drawn immediately after adding 126 lb methoxyethanol while circulating.

TABLE 24. TANK "B" TEST RESULTS

Date of Sampling: / Days of Incubation:	25 Oct 99	28 Oct 102	4 Nov 109	11 Nov 116	18 Nov 123	22 Nov 127
Total Count per ml						
Fuel	0*	10	0	10	0	0
Interface					**	1,440,000
Water	61,000*	285,000	82,000	1,600,000	**	5,100,000
Bacteria Identified* **						
Facultative anaerobes	+	+	+	+		+
Obligate anaerobes						-
Sulfate reducers	+	+	+	+		+
Iron depositors	+	+	+	+		+
Fungi						
Fuel	+	-	-	-		-
Interface						+
Water	+	+	-	+	+	-
Miscellaneous						
Fuel sampling temp, °F		78	75	75	74	75
Interfacial tension, dynes/cm						37.4
Millipore solids, mg/liter						1.2
pH of water	5.4	5.5	5.5	5.5	5.6	5.6

*Samples drawn immediately after pumping.

**Heavy confluent growth prevented accurate counting.

***Pseudomonas aeruginosa, a coliform type, and Proteus sp. identified in 11 Nov sample; two types of mucoid colonies, yellow and cream colored, observed in 22 Nov samples.

	4 Oct	10 Oct
Water - before	30,000	300,000
- after	500,000	50,000
Interface - before	700,000	60,000
after	300,000	600,000

The results from the test on 4 October seemed logical in that any disturbance would be expected to disperse microorganisms from the interface through the water layer. However, the discrepancies between the two sets of results simply point out the virtual impossibility of obtaining a representative or reproducible sample from a large container. The tendency of the bacteria to clump is undoubtedly a contributory factor, and such clumping also makes it difficult to obtain accurate counts. Further, no technique used in drawing samples can possibly give repeatable samples, since each sample merely represents one particular point in space and time in a heterogeneous system that is changing rapidly. With these factors in mind, it becomes evident that even order-of-magnitude agreement between counts on successively drawn samples may not always be possible.

On 25 October, the small quantity of fuel and water in Tank B was transferred to Tank A with a hand pump. It should be pointed out that a small amount of water had passed over into Tank B during the first few back-and-forth transfers after the water bottoms had been added to Tank A, thus dropping the water level in Tank A just enough to prevent further pickup in the pump suction. After all had been transferred back to Tank A, recirculation of the contents for one hour gave mixing of both the fuel and water. Then the fuel and water phases were each divided equally between the two tanks. Microbial counts on samples from the two tanks at this time showed equivalence (57,000 and 61,000 per ml). Next, over a period of 1.5 hours while recirculating the fuel in Tank A, a total of 126 lb of methoxyethanol was injected into the pump suction, thus giving a water bottoms in Tank A containing 20% methoxyethanol. Although the methoxyethanol was injected into the circulating fuel, it may be assumed that it migrated to the water bottoms fairly rapidly, aided by the circulation. Five minutes after pumping ceased, samples drawn from the water bottoms of Tank A showed no significant change in total count.

Subsequently, both tanks were sampled at intervals without further pumping or disturbance. The following total-count data on water bottoms samples are of particular interest:

Days after Treatment of Tank A	Total Count per ml	
	Tank A	Tank B
0	43,000	61,000
3	0	285,000
10	0	82,000
17	0	1,600,000
24	30	-
28	3	5,100,000

Thus, the addition of 20% methoxyethanol to the water bottoms in Tank A sterilized the water within three days and maintained sterile or near-sterile conditions for four weeks. The untreated water bottoms in Tank B showed a marked increase in microbial population during this period. It is of interest to note that only a moderate rate of growth was observed in Tank A during the approximately three months between the inoculation and the methoxyethanol treatment. One month later, the portion transferred to Tank B had shown a considerable increase in population. Possibly the microorganisms growing in Tank B during the earlier period, when the tank was nearly empty most of the time, started multiplying rapidly when given a new and larger source of nutrient. However, the frequent transfers between tanks during this period should have favored qualitative similarity of the species compositions of the two tanks, i.e., transfer of the species in Tank B to the larger source of nutrient in Tank A. Another possible explanation is that the lower temperatures during October and November (75-80°F), after splitting the contents between the two tanks, were more favorable than the earlier 80-90°F tank temperatures for the growth of the predominant microorganisms.

It is also interesting to note that both sulfate-reducing and iron-depositing microorganisms were detected in Tank B but not in Tank A during the last four weeks of the program. It is possible that these species had existed in both tanks prior to that time, as no assays had been made. The prior existence of these species in Tank B but not in Tank A is considered rather unlikely, in view of the frequent transfers between tanks. Also, all of the fuel and water in Tank B had been hand-pumped to Tank A at the time the contents were to be split between the two tanks, and this would be expected to inoculate Tank A with any "foreign" microorganisms present in Tank B. In any case, the methoxyethanol that was then added to Tank A either killed off the iron depositers and sulfate reducers, or at least suppressed their growth.

There was a distinct difference in the appearance of the water bottoms and interface samples taken from the two tanks. The Tank A samples always contained reddish-brown particles and coagulated matter; the Tank B samples contained in general more particles and coagulated matter and were a very

dark chocolate-brown color. Possibly the red iron oxide that had been added to Tank A during circulation at various times contributed to the difference in color. Since Tank B was near empty during most of the program, it seems likely that a considerable amount of rust and possibly fuel gums would have been developed.

The total-count plates on water and interface samples from both tanks usually showed colonies of a light cream color, opaque, circular in shape, and convex in cross section, with a strong disagreeable odor. On many of the plates in the early part of the program, up through the samples of 10 October, the colonies were surrounded by a clear area indicating inhibition of growth, possibly through the action of bacteriophages.

In one of the water samples taken from Tank B during the last month of the program, Pseudomonas aeruginosa, a coliform type, and a Proteus species were identified. In another sample, two types of mucoid colonies were observed, yellow and cream colored.

The pH of the water bottoms in the two tanks was recorded during the last two months of the test. These values proved to be quite uniform, with Tank A starting at 5.3 and decreasing to 5.0, and Tank B starting at 5.4 and increasing to 5.6. Although no pH values were recorded on the water bottoms during the first three months of storage, rechecks have been made on fresh blends of 5% sea water, with and without anti-icing additive. These values were all in the 6.8-7.2 range.*

The outstanding result of this tank storage program is the virtually complete sterilization of the one tank bottoms by the addition of 20% methoxyethanol. This occurred within three days and was maintained for one month (to the end of the program), with only stray microorganisms being found after the treatment.

*Neutral pH values were also obtained on aqueous blends after storage under JP-4 fuel for several days.

V. EXPERIMENTAL PROGRAM - DRUM STORAGE TESTS

A. General

In order to investigate the effect of anti-icing additive on the growth of microorganisms under controlled conditions, it is necessary to conduct tests in relatively small-scale static systems, from which extraneous microorganisms can be excluded. On the other hand, experiments conducted entirely in conventional small-scale glassware (culture tubes, plates, or flasks) suffer from a certain lack of realism in relation to field fuel handling equipment. A reasonable compromise can be achieved by the use of intermediate-size equipment and by including some of the materials that are present in operating systems - in particular, typical metals and coatings.

For the present program, it was decided to set up a series of tests in 15-gallon drums containing JP-4 fuel and dilute sea water bottoms with varying percentages of glycerin and methoxyethanol. Bare and coated metal surfaces were provided in the form of specimen strips. The water bottoms were inoculated with a composite of selected microorganisms, and the assemblies were left undisturbed for 19 weeks during the summer and fall of 1963. Data were obtained on microbial populations and types and on fuel and water properties. Auxiliary information was obtained on corrosion and effects on the coating materials.

This portion of the program was conducted concurrently with the tank storage tests described in Section IV.

B. Test Equipment and Materials

The test containers were 15-gallon epoxy-lined steel drums. These were standard 20-gage steel drums with 2" and 3/4" bungs. According to the manufacturer, the lining consisted of two coats of BV-Sterilkote baked epoxy.

The JP-4 fuel, glycerin, methoxyethanol, microbial inoculant material, and natural sea water used in the drum tests were taken from the same stock used in the tank storage tests. Distilled water was used in making up the water bottoms for the drum tests.

The steel used for corrosion and coating specimens was 0.075" steel tank plate (ASTM A415-58T 14 gage), and the aluminum specimens were cut from 0.090" plate (5052).

Two MIL-C-4556B coating systems were used on the steel specimens; one of these was an epoxy type and the other a furan type.

C. Test Program and Procedures

1. Setting Up Drum Tests

The empty drums were autoclaved with bungs loosened for 45 minutes at 12 psig and allowed to cool in the autoclave, after which they were removed and the bungs were tightened at once. These sterilized drums remained closed until ready for charging the test materials.

Each drum was charged with ten gallons of JP-4 fuel that had been pumped under sterile conditions through a 0.45-micron Millipore filter.

Sterile distilled water and autoclave-sterilized natural sea water were used in making up the water bottoms. The methoxyethanol and glycerin were used as received.

After adding the required amounts of glycerin and methoxyethanol to each drum, the sea water and part of the distilled water was added. Then 5 ml of the composite inoculant material was dispersed in 500 ml of distilled water and added to the drum. Finally, the remainder of the distilled water was added, and the drums were bunged tight.

Each water bottom consisted of one gallon of water, of which 5% by volume was sea water, plus methoxyethanol and glycerin in varying amounts. Thus, the ratio of aqueous phase to fuel varied from 1/10 to about 1/8 depending on the amounts of methoxyethanol and glycerin. These ratios are sufficiently high that the composition of the water bottoms will be essentially unchanged by the minor amounts of additive that are retained by the fuel; likewise, the water bottoms composition will remain essentially constant regardless of temperature changes.

The calculated initial count of the water bottoms, assuming uniform distribution of the inoculant, was 2800 to 3400 microorganisms per milliliter.

Two of the drums were inoculated with the University of Dayton bacterial and fungal cultures only; i.e., the raw Bergstrom culture was omitted.

After charging the drums, they were left sealed until the coating and corrosion specimens were introduced.

The composition of the water bottoms in these drums is shown in Table 25.

TABLE 25. ORIGINAL COMPOSITION OF WATER BOTTOMS IN DRUM TESTS

Drum Nos.*	Composition, Weight Percent		
	Methoxyethanol	Glycerin	Water**
1 and 1S	0	0	100
2 and 2S	1	0	99
3 and 3S	2	0	98
4 and 4S	5	0	95
5 and 5S	0	1	99
6 and 6S	2	1	97
7 and 7S	10	1	89
8 and 8S	20	1	79
9 and 9S	10	10	80
10	20	1	79
11	0	0	100

*Drums 10 and 11 were inoculated with UD cultures only; all other drums were inoculated with composite UD-Bergstrom culture. The drums designated "S" contained a four-strip specimen assembly; the drums designated by number only contained one bare steel strip.

**5% sea water and 95% distilled water by volume.

2. Preparation of Coating and Corrosion Specimens

The steel and aluminum were sheared to 1" X 23-1/2" strips, and sharp edges and corners were broken by filing. Holes (3/8" D) were drilled in the ends of the strips. The steel strips were sandblasted to bare metal and immediately sealed in desiccated containers and purged with nitrogen; they remained in this atmosphere until ready for coating or final cleaning and assembly.

The steel strips to be coated were first dry-brushed and then degreased with trichloroethylene. They were then brushed or dip-coated with primer of one or the other coating system. When dip-coating was used, the specimens were withdrawn at 1.5 in./min. Prime coat thicknesses varied between 1 and 2 mils on all strips, as measured with an Elcometer and rechecked by a representative of one of the coating manufacturers, using a different instrument. The topcoats in the furan coating system were applied readily by dip-coating with a 3.4 in./min withdrawal rate, but the topcoats in the epoxy system were too thick for dipping. After considerable experimentation, it was found that spray-coating of a thinned material gave satisfactory results. Both the furan and the epoxy systems were applied with alternating coats of gray and black topcoating until the total thicknesses including prime coat were 12 mils for the furan and 15 mils for the epoxy. The furan coatings were air-cured 5 days, and the epoxy coatings were oven-cured 48 hours at 140°F prior to placing the specimens in the drums. No attempts were made to sterilize the coated strips, in view of reports by Battelle* that sterilization is unnecessary for this type of work and may lead to changes in coating properties.

The bare steel and aluminum strips were cleaned by wiping and rinsing in benzene, acetone, and finally trichloroethylene. The bare metal strips and also the Teflon and steel hardware used in assembly were oven-sterilized. Rubber gloves sterilized in alcohol were used in handling and assembling the components of the assemblies.

The configuration of the specimen assemblies is shown in Figure 5. The order of assembly was the same in all cases: epoxy-coated steel, bare aluminum, bare steel, and furan-coated steel. The strips were bolted together with Teflon studs and steel nuts with Teflon spacers and washers to insulate the strips from each other.

As each specimen assembly was completed, it was placed in the respective drum (series 1S through 9S). In a similar manner, a single bare steel strip was placed in each of the other drums. Nine drums with specimen

---

*Cooper, C. W., Kemp. H. T., and Kell, R. M., "Elastomers for Fuel Systems Containing Microorganism-Controlling Additives," RTD-TDR-63-4195, 31 Dec 1963.

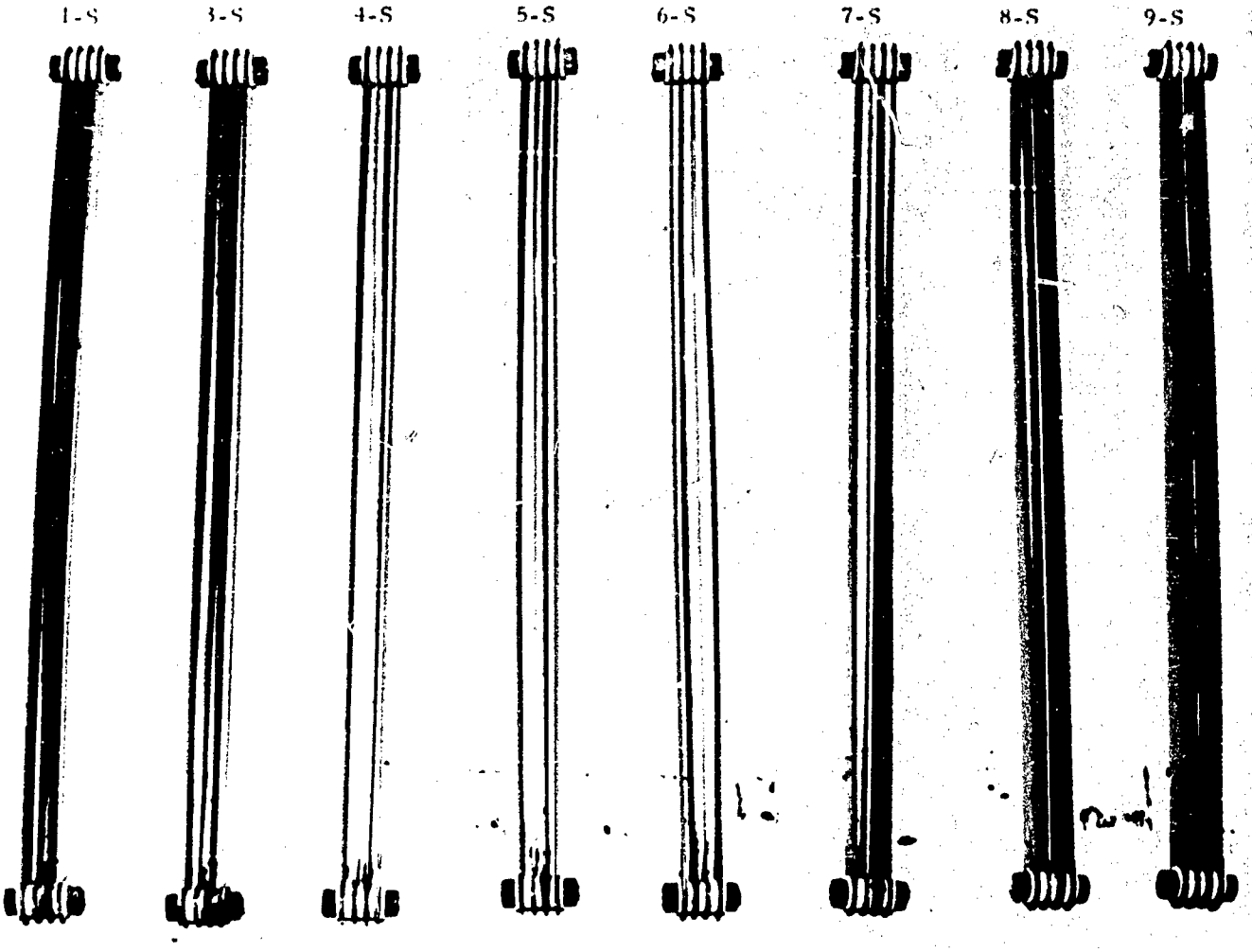


FIGURE 5. CORROSION STRIP ASSEMBLIES

assemblies and nine with single steel strips were set up initially, and two more drums (the UD cultures only) were set up with single steel strips some 25 days later.

3. Storage Schedule and Conditions

The test drums were left without agitation or aeration during the test period. The summarized storage test schedule is shown in Table 26. The drums were sampled at five weeks and again at 19 weeks at the end of the test. During the first five to six weeks, in July and August, the drums were stores in a closed shed. The ambient temperature during this period ranged from about 75 to 100°F. and fuel temperstures were 87 to 94°F at the time of sampling. For the latter period of storage, the drums were moved to an open shed. Temperatures of the fuel during sampling in November ranged from 63 to 103°F.

4. Sampling Techniques

The intermediate (five-week) sampling was performed by siphoning samples of fuel and water through sterile tubing into sterile glass bottles, with minimum opening of the drums.

The final sampling involved collection of interface material from the corrosion strips, as well as water bottoms samples to test for anaerobes, plus the normal fuel and water samples. The sampling routine to obtain these material involved a number of steps. All sampling equipment and containers for microbiological samples were presterilized by autoclaving or by dry heat, as applicable. Once the drum was opened and the position of the corrosion specimens verified, the sampling was performed according to the following sequence:

(a) Siphon fuel through glass and vinyl tube assembly from 4" below the surface into a vial for microbial count.

(b) Fill a 250-ml bottle with fuel from this same location, for test for anti-icing additive content.

(c) Draw from same location into a 1-qt bottle; rinse and discard; then fill bottle (for water content and interfacial tension).

(d) Using the same glass tube, scrape along the metal specimens near the fuel-water interface and simultaneously fill a vial (for interface microbial count).

TABLE 26. SUMMARIZED LOG OF DRUM STORAGE TESTS

Date	Days of Test: Drums 1-9 & 1S-9S	Days of Test: Drums 10-11	Remarks
12 Jul	0	-	Set up Drums 1-9 and 1S-9S with JP-4 and selected quantities of glycerin and methoxyethanol. Added composite inocula material.
13 Jul	1	-	Specimens 1-9 and 1S-9S were placed in their respective drums.
6 Aug	-	0	Set up Drums 10 and 11 with JP-4 and selected quantities of glycerin and methoxy ethanol. Added University of Dayton inocu
7 Aug	-	1	Specimens 10 and 11 were placed in their respective drums.
19 Aug	38	13	Started collecting intermediate samples.
23 Aug	42	17	Finished collecting intermediate samples. Moved drums to open storage shed.
4 Nov	115	90	Started collecting final samples.
21 Nov	132	107	Finished collecting final samples.
22 Nov	133	108	Removed all corrosion specimens from drums.

(e) Using the same glass tube, fill a 250-ml bottle with water bottoms (for pH, glycerin and methoxyethanol content, and interfacial tension).

(f) Using a syringe with long tube, draw material from bottom of drum directly under metal specimens. Replace long tube with regular needle and inject part of sample into sterile, nitrogen-filled serum bottle (for anaerobic bacteria tests).

(g) Inject remaining sample from syringe into vial (for water bottom microbial count).

(h) Measure fuel temperature 6" below surface, and reseal drum.

For these final samples, the microbiological assays were started within one hour after sampling. In some of the supplementary identification work, there was a ten-day lapse between sampling and culturing, as will be noted in the discussion.

The metal specimens were removed for examination after all of the fuel and water samples had been taken. This involved a time lapse of from 1 to 18 days (see Table 26).

5. Analytical and Microbiological Procedures

A listing and discussion of the test methods used in this program is given in Appendix A. Two different methods were used for the anti-icing additive content of fuel samples, and two different methods for the glycerin and methoxyethanol contents of water samples, as indicated in the text and tables. The microbial total counts were all conducted by the use of TSA spread plates.

D. Test Results and Discussion

1. Fuel and Water Properties

The results of chemical and physical tests on the intermediate and final samples from the drum storage tests are shown in Tables 27 and 28, respectively.

The outstanding fact to be noted in these results is the low pH values reached by the water bottoms at the end of the test, ranging from 4.0 to 5.4. For the intermediate samples, there were definite trends in pH: In

TABLE 27. PROPERTIES OF INTERMEDIATE DRUM STORAGE SAMPLES

Drum No.	Water Bottoms					Fuel Samples		
	Nominal		Analysis			Water**,	AIA, Vol %	
	% M*	% G*	% M*	% G*	pH	mg/liter	by FP	Titration
1	0	0	-	-	6.3	98	0.000	-
1S	0	0	-	-	5.4	90	0.000	-
2	1	0	0.5	-	5.4	92	0.000	0.001
2S	1	0	0.8	-	5.1	103	0.000	-
3	2	0	1.8	-	5.4	97	0.004	0.003
3S	2	0	1.7	-	5.3	90	0.004	-
4	5	0	4.3	-	4.7	70	0.018	0.019
4S	5	0	4.3	-	4.2	74	0.018	-
5	0	1	0	2.0	6.1	84	0.000	0.000
5S	0	1	0	2.7	5.1	91	0.000	-
6	2	1	1.8	2.0	4.7	87	0.008	0.005
6S	2	1	1.7	1.5	5.2	83	0.008	-
7	10	1	8.5	1.8	6.6	72	0.045	0.047
7S	10	1	8.5	1.6	6.5	71	0.045	-
8	20	1	17.4	1.7	7.3	77	0.110	0.111
8S	20	1	17.4	2.2	6.1	79	0.110	-
9	10	10	8.6	10.7	6.0	84	0.054	0.057
9S	10	10	8.9	11.0	7.0	96	0.054	-
10	20	1	17.7	1.6	7.4	72	0.090	0.076
11	0	0	-	-	5.6	88	0	-

*Weight % methoxyethanol and glycerin as set up and as determined by distillation-R.I. method.

**Fuel temperature in drums 87-94°F at time of sampling.

TABLE 28. PROPERTIES OF FINAL DRUM STORAGE SAMPLES

Drum No.	Water Bottoms						Fuel Samples		
	Nominal		Analysis				Sampling	Water,	AIA, Vol %
	% M*	% G*	% M*	% G*	pH	IFT**	Temp, °F	mg/liter	by Titration
1	0	0	0.5	-	4.8	36.7	68	84	0.000
1S	0	0	1.0	-	4.6	37.2	72	71	0.000
2	1	0	1.7	-	4.4	35.6	103	66	0.000
2S	1	0	2.0	-	4.1	33.7	80	76	0.000
3	2	0	2.7	-	4.6	36.5	84	79	0.003
3S	2	0	3.3	-	4.4	37.7	68	61	0.003
4	5	0	5.4	-	4.2	32.7	84	86	0.013
4S	5	0	5.8	-	4.0	31.9	73	44	0.008
5	0	1	0.2	0.8	4.7	33.6	68	62	0.000
5S	0	1	1.2	0.6	4.6	39.5	63	50	0.000
6	2	1	3.2	0.9	4.2	33.8	70	62	0.003
6S	2	1	2.6	0.8	5.2	37.4	80	48	0.003
7	10	1	10.2	0.7	4.9	26.2	80	72	0.030
7S	10	1	10.7	0.8	5.1	30.3	77	55	0.027
8	20	1	19.8	1.0	5.0	25.1	71	66	0.078
8S	20	1	20.0	0.9	5.4	23.1	70	73	0.077
9	10	10	10.0	***	4.4	26.5	75	82	0.036
9S	10	10	10.1	***	4.3	28.9	75	74	0.035
10	20	1	20.9	0.9	4.9	23.2	76	78	0.082
11	0	0	2.5	-	4.6	35.2	76	65	0.000

*Weight % methoxyethanol and glycerin as set up and as determined by periodate method for glycerin and R.I. of total product for methoxyethanol content. The R.I. correlation was applied using the correction for the nominal glycerin content, not the glycerin content found by analysis.

**Interfacial tension of fuel sample over corresponding water bottoms sample, dynes/cm.

***Unable to analyze by method as furnished.

the series 1 through 4 (no glycerin, 0 to 5% methoxyethanol), there was a decrease in pH with increasing methoxyethanol content. In the series 5 through 8 (1% glycerin, 0-20% methoxyethanol), there was first a decrease in pH with 2% methoxyethanol, then increases at 10 and 20% methoxyethanol, which correspond to some inhibition of microbial growth. However, in the final samples, all of these trends were more or less obliterated, and all of the pH values were in the lower range.

Although the initial drum setups before storage were not sampled for pH determinations, synthetic blends of the same composition showed pH values in the 6.8-7.2 range* The decreases in pH of the final storage samples could not be correlated successfully with concentration of either ingredient (glycerin or methoxyethanol), the presence or absence of coated strips, or the degree of microbial growth. The fairly uniform decreases in pH that were observed suggest that some unknown factor, common to all the drum setups, was overriding the effects of composition and microbiological changes. It is conceivable that nonbiological oxidation of the fuel itself, or even a slow extraction of acidic material from the fuel or from the interior coating of the drums, could be responsible for the low pH values at the end of the test.

At the termination of the drum storage tests, the pH of the water bottoms in many of the drums was approaching the minimum tolerable limit (4.0) for most bacteria. Since the minimum tolerable limit for most fungi is somewhat lower (2.0), it is possible that subsequent growth would show a relative increase in fungi and a decrease in bacteria.

The water contents of the fuel layers were found to be lower for the final samples than for the intermediate samples, which merely reflects the generally lower temperatures in the final sampling. The intermediate samples showed a trend toward lower water contents for the drums with high percentages of anti-icing additive in the water bottoms. However, this trend was not apparent in the final samples, where the water contents showed a random distribution around the solubility-temperature curve of the base fuel. The random variation was attributed to the fluctuating temperatures of the drums, which would prevent the attainment of equilibrium water content. Controlled small-scale experiments would be needed to settle the question of whether the water solubility in fuels ("saturation limit") is affected significantly by the methoxyethanol concentrations present in storage tank water bottoms.

The anti-icing additive contents of the fuel phase in the drums were in general agreement with published partition coefficients and with field experience. The concentrations were lower in the intermediate samples than in the final samples, as expected, because of the higher average temperatures of the drums at the intermediate sampling. The freezing point and titration methods for anti-icing additive content gave good agreement of results.

*Neutral pH values were also observed on the aqueous blends after storing several days under JP-4 fuel.

The analyses of the water bottoms for methoxyethanol and glycerin contents were performed by the SwRI distillation-R.I. method (intermediate samples) and by periodate oxidation for glycerin and R.I. correlation for methoxyethanol (final samples). Details of these two methods are given in Appendix A. Neither of these schemes is entirely satisfactory, and the data shown in Tables 27 and 28 must be regarded as more a check on the validity of the test methods than any indication of significant changes during storage. Some of the problems with the periodate oxidation and the R.I. correlation have since been worked out, but it has not been feasible to recheck the data on the drum storage samples.

The interfacial tension values obtained on each fuel-water combination showed the usual inverse relation between IFT and methoxyethanol content of the water bottoms, which obscured any minor effects that may have been attributed to microbial action or changes in surfactant properties. About the only out-of-line value was on Drum 5, where the IFT was unexplainably low.

2. Microbiological Assays

The results of the microbiological assays are shown in Table 29. Details on the assay methods are given in Appendix A.

The intermediate water bottom samples taken after 38-40 days from Drums 1-9 and 1S-9S, and after 13-17 days from Drums 10 and 11, indicated appreciable increases in total count above the initial calculated value (about 3000) in only five drums - 5, 5S, 6, 6S, and 11. None of these drums contained more than 2% methoxyethanol in the water bottoms. Glycerin at 1% concentration seemed to promote growth (Drums 1 and 1S vs 5 and 5S).

At the level of 20% methoxyethanol, the drums with composite inoculant (8 and 8S) showed no significant change, while the drum with UD cultures only (10) was entirely sterile. This would imply that the "wild" Bergstrom microflora, which had been growing in tank bottoms containing on the order of 20-30% methoxyethanol, had become somehow adapted to this environment and hence could survive at the 20% methoxyethanol concentration in the drum tests. The total sterility of Drum 10 was not maintained through the final sampling, which gave total counts on the order of the original inoculation. Possibly foreign microorganisms were introduced during the intermediate sampling or during the final storage period. The latter is considered possible in view of the exposure of the drums to two driving rains during this period, although under roof. Water covered the drum heads and bungs for several hours before it was removed, and, although the drums were bunged tight, it is likely that traces of the rain water were ingested.

TABLE 29. MICROBIOLOGICAL ASSAYS OF SAMPLES FROM DRUM STORAGE

Drum No.	As Set Up		Intermediate Samples (Water Bottoms)*			Final Samples								
						Total Count per ml**			Fungi**			Special Assays***		
	% M	% G	Total/ml	Anaer.	Fungi	Water	I'face	Fuel	Water	I'face	Fuel	Anaer.	S-Red.	Fe-Dep.
1	0	0	4,200	+	+	1,200,000	1,800,000	0	-	-	-	-	-	+
1S	0	0	4,800	+	+	5,000,000	5,500,000	0	-	-	-	+	-	+
2	1	0	880	-	-	700	11,000	0	-	-	-	-	-	+
2S	1	0	340	-	+	51,000	6,000	10	+	-	-	+	-	+
3	2	0	250	-	-	224,000	560,000	0	+	+	+	+	-	+
3S	2	0	720	-	-	9,600,000	380,000	0	-	-	-	-	-	+
4	5	0	9,000	+	+	30,000	97,000	+	-	-	-	+	-	+
4S	5	0	8,500	+	+	390,000	1,600,000	0	-	-	-	+	-	-
5	0	1	300,000	-	+	130,000	150,000	0	-	-	-	+	-	+
5S	0	1	45,000	+	+	1,900,000	2,200,000	0	-	-	-	+	-	+
6	2	1	53,000	+	+	15,000	15,000	0	+	+	+	+	-	+
6S	2	1	100,000	+	+	2,370,000	2,490,000	0	-	-	-	+	-	+
7	10	1	11,500	+	-	7,000	8,000	0	+	+	-	+	-	+
7S	10	1	1,050		+	2,700,000	720,000	0	-	-	-	-	-	-
8	20	1	1,250	+	+	4,800	4,800	0	-	-	-	-	-	-
8S	20	1	2,000	+	-	500	700	0	-	-	-	-	-	-
9	10	10	500	-	+	0	400	0	-	-	-	-	-	-
9S	10	10	1,000	-	+	3,500	0	0	-	-	-	-	-	-
10	20	1	0		-	3,300	5,900	0	-	-	-	-	-	-
11	0	0	30,000		-	800	1,900	0	+	-	-	+	-	+

*Fuel samples at intermediate sampling all gave zero count.

**Total-count plates on final samples: Drums 1, 4S (water) - some colonies of Staphlyococcus aureus.
Drums 5, 6S, 11 (water) - mucoid growth.
Drum 8 (interface) - dry crumbly growth.
Fungi in Drum 3 (interface) - Aspergillus.

***Anaerobes checked on water sample collected with minimum air exposure. Sulfate reducers and iron depositors checked on interface samples.

Another comparison of the Bergstrom and UD cultures is given by the final samples from the drums with no anti-icing additive. The 10^6 counts on Drums 1 and 1S (composite inoculant) and the 10^3 counts on Drum 11 (UD only) indicated that the Bergstrom culture probably was more readily adaptable to the drum storage conditions.

No viable microorganisms were found in the fuel phase at the intermediate sampling and only minor indications at the final sampling. This is in line with the vast majority of field experience indicating that the site of growth is water and interface and that "clean" fuel is essentially sterile.

In the final samples, the water and interface total counts showed that 20% methoxyethanol, or 10% methoxyethanol and 10% glycerin, was very effective in preventing growth. The highest counts, one as high as 10^7 and several of 10^6, were observed on drums with 0-2% methoxyethanol. No clear-cut effect from the presence or absence of 1% glycerin could be observed. There was a very definite trend toward higher counts on the drums containing the specimen assemblies, in comparison with the steel strips only; this trend had not been apparent on the intermediate samples. Apparently either the coatings or the aluminum had contributed to microbial growth, or possibly the phenomenon was merely that of added surfaces for growth. In any case, it was quite evident that the coated strips did not contribute any growth-retarding effect, and if anything the reverse was true.

The presence of facultative anaerobes was indicated qualitatively in about half of the water samples at both sampling periods (collected with minimum air exposure in the final sampling). Fungi were found quite regularly in the water layer in the intermediate sampling but were detected in only five drums in the final sampling. Tests for sulfate reducers on the final samples were negative throughout; iron depositors were found in about half the samples. The absence of sulfate reducers and of any strict anaerobes is not too surprising, as no such microorganisms were introduced with the inoculant. This situation is in contrast with that in the 4000-gallon Tank B in this program, where sulfate-reducers were found. Although this tank had the same inoculants as the drums, it also had free access of extraneous microorganisms - those originally present on the tank surfaces, those introduced with the nonsterile tap water, and those ingested through the air vent.

After the regular assays had been completed, some additional tests were made to further classify or identify the microorganisms. The samples had been kept for as much as ten days before performing these supplementary tests, and many species undoubtedly did not survive this period. For example, the samples from Drums 2, 2S, 8, 8S, 9, and 9S had no viable

bacteria at all. The methods used are discussed in Appendix A The results of the supplementary tests are shown in Table 30.

Immediately after the metal specimens were removed from the drums, several samples of deposited matter were scraped from those areas in contact with the water, dispersed in distilled water, and checked for the presence of various types of microorganisms, using the methods described in Appendix A. The test medium for fungi in this case was Rose Bengal-Streptomycin agar. The results of these tests are shown in Table 31. All of the samples gave positive tests for bacteria on TSA, two of them showed gas-formers, all but one showed iron-depositors, and all but two showed fungi. The data were not extensive enough for any correlation of type of microorganisms with type of metal or coating. Possibly the significant point here was the fact that scrapings from both of the coated strips contained viable bacteria. This is qualitative confirmation of the lack of any biocidal effect of the coatings.

3. Examination of Metal and Coating Specimens

Although investigation of coatings and metal corrosion was not a direct objective of this program, the specimens were examined qualitatively after test. As described previously, Drums 1-11 each contained a single bare steel strip (used to provide a source of iron for the microorganisms), and Drums 1S-9S each contained an assembly of bare steel, bare aluminum, and two coated steel specimens. In each drum, the specimen or assembly rested diagonally across the drum with the lower end on the bottom of the drum against the drum wall, and the other end leaning against the opposite wall. The specimen or assembly formed an angle of about 50° with the bottom of the drum. The single strips were set in the drums with a flat side facing upward, but the assemblies were inserted so that each strip had an edge facing upward. The height of the fuel in the drums was about 15 inches, and the height of the water about 2 inches. Thus, all specimens were exposed to water, fuel, and air phases.

All of the single steel strips (Drums 1-9) were heavily corroded in the water layer, moderately corroded in the air space, and in general very lightly corroded in the fuel phase. As shown in Figures 6-11, the upward-facing sides of the strips showed more corrosion than the reverse side. Air-space and fuel-phase corrosion were rated in order of decreasing severity:

	(Most)	(Least)
Air-space - Drum No.	1, 2, 5, 3, 6, 4, 11, 9, 7, 10, 8	
Fuel-phase - Drum No.	2, 11, 6, 4, 10, 8, 1, 3, 7, 5, 9	

TABLE 30. SUPPLEMENTARY ASSAYS ON DRUM STORAGE SAMPLES

Sample	Bacteria: On Trypticase Soy Agar	Bacteria: In Lactose Broth	Gas Forming	Coliforms	Fungi
Drum 1					
Fuel					+
Water	+	+	2*	+	+ Hormodendrum
Interface	+	+	1	-	+ Penicillium
Anaerobic	+	+	2	+	
Drum 1S					
Fuel					-
Water	+	+	1	+	-
Interface	+	+	-		-
Anaerobic	+	+	2	+	-
Drum 2					
Fuel					-
Water	-	-	-	-	-
Interface	-	-	-	-	-
Anaerobic	-	-	-	-	-
Drum 2S					
Fuel					-
Water	-	-	-	-	-
Interface	-	-	-	-	-
Anaerobic	-	-	-	-	-
Drum 3					
Fuel					-
Water	+	+	1		+ Hormodendrum
Interface	+	+	1	-	-
Anaerobic	+	+	1	+	-
Drum 3S					
Fuel					-
Water	+	+	1	+	-
Interface	-	-	-		-
Anaerobic	+	+	1	+	-

*Numbers 1, 2, 3 and 4 indicate relative amounts of gas trapped in the inverted test tube.

TABLE 30. SUPPLEMENTARY ASSAYS ON DRUM STORAGE SAMPLES (Cont'd)

Sample	Bacteria: On Trypticase Soy Agar	Bacteria: In Lactose Broth	Gas Forming	Coliforms	Fungi
Drum 4					
Fuel					-
Water	+	+	-		-
Interface	+	+	-		+ Hormodendrum
Anaerobic	+	+	-		-
Drum 4S					
Fuel					-
Water	+	+	-		-
Interface	-	-	-		-
Anaerobic	+	+	-		-
Drum 5					
Fuel					-
Water	+	+	1	+	-
Interface	-	-	-		-
Anaerobic	+	+	3	+	-
Drum 5S					
Fuel					-
Water	+	+	2	+	+ Penicillium, Fusarium
Interface	+	+	1	-	-
Anaerobic	+	+	2	+	-
Drum 6					
Fuel					-
Water	+	+	2	+	+ Paecilomyces
Interface	+	+	1	-	+ Hormodendrum
Anaerobic	+	+	4	+	-
Drum 6S					
Fuel					-
Water	+	+	1	+	-
Interface	+	+	1	+	-
Anaerobic	+	+	1	+	-
Drum 7					
Fuel					-
Water	+	+	-		-
Interface	+	+	-		-
Anaerobic	+	+	-		-

TABLE 30. SUPPLEMENTARY ASSAYS ON DRUM STORAGE SAMPLES (Cont'd)

Sample	Bacteria On Trypticase Soy Agar	Bacteria In Lactose Broth	Gas Forming	Coliforms	Fungi
Drum 7S					
Fuel					-
Water	+	+	-		-
Interface	+	+	-		-
Anaerobic	+	+	-		-
Drum 8					
Fuel					-
Water	-	-	-		+ Alternaria
Interface	-	-	-		-
Anaerobic	-	-	-		-
Drum 8S					
Fuel					-
Water	-	-	-		-
Interface	-	-	-		-
Anaerobic	-	-	-		-
Drum 9					
Fuel					+
Water	-	-	-		-
Interface	-	-	-		-
Anaerobic	-	-	-		-
Drum 9S					
Fuel					+
Water	-	-	-		-
Interface	-	-	-		-
Anaerobic	-	-	-		-
Drum 10					
Fuel					-
Water	+	+	-		-
Interface	+	+	-		-
Anaerobic	-	-	-		-
Drum 11					
Fuel					-
Water	+	+	+	+	+ Alternaria
Interface	+	+	+	+	-
Anaerobic	+	+	+	+	-

TABLE 31. PRESENCE OF BACTERIA AND FUNGI IN DEPOSITS SCRAPED FROM CORROSION STRIPS

Source of Scraping*	Bacteria		Gas Forming Bacteria	Iron Depositing Bacteria	Fungi
	On Trypticase Soy Agar	In Lactose Broth			
1S, steel	+	+	-	-	+
1S, aluminum	+	+	-	+	+
6S, steel	+	+	+	+	+
6S, aluminum	+	+	+	+	+
7S, aluminum	+	-	-	+	+
7S, epoxy	+	-	-	+	+
8S, steel	+	-	-	+	-
9S, furan	+	-	-	+	-

*Scrapings came from that part of the strips that had been in the water.

FIGURE 6. UPPER SURFACES OF STEEL STRIPS

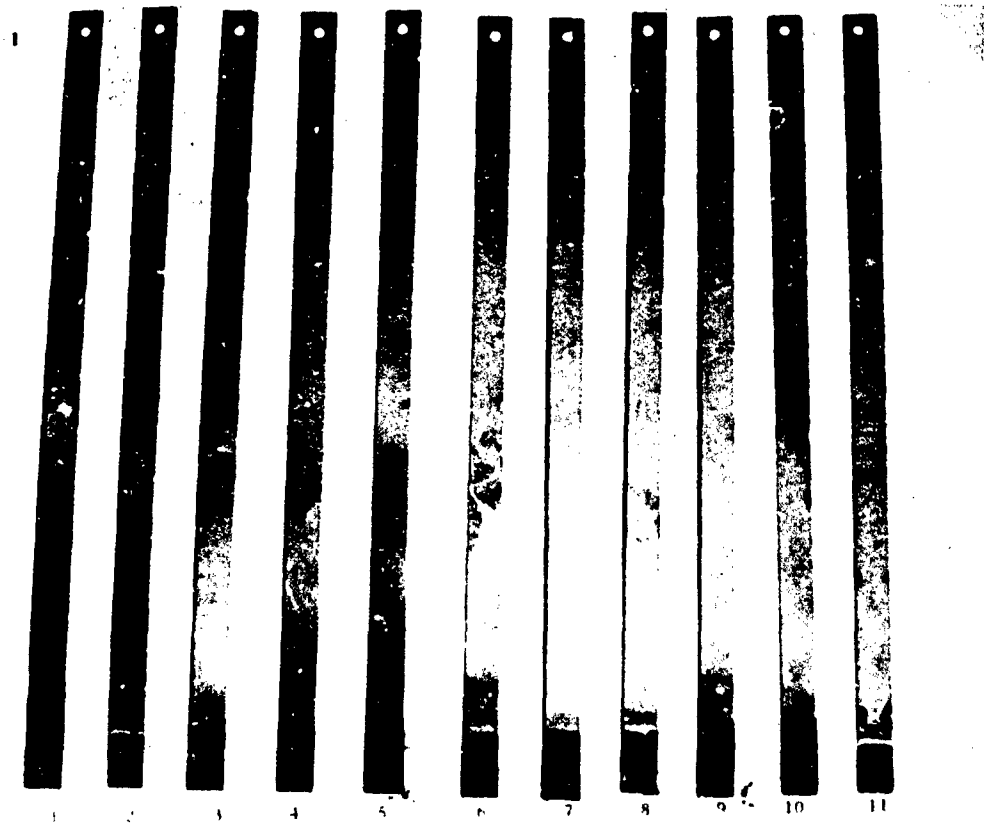


FIGURE 7. LOWER SURFACES OF STEEL STRIPS

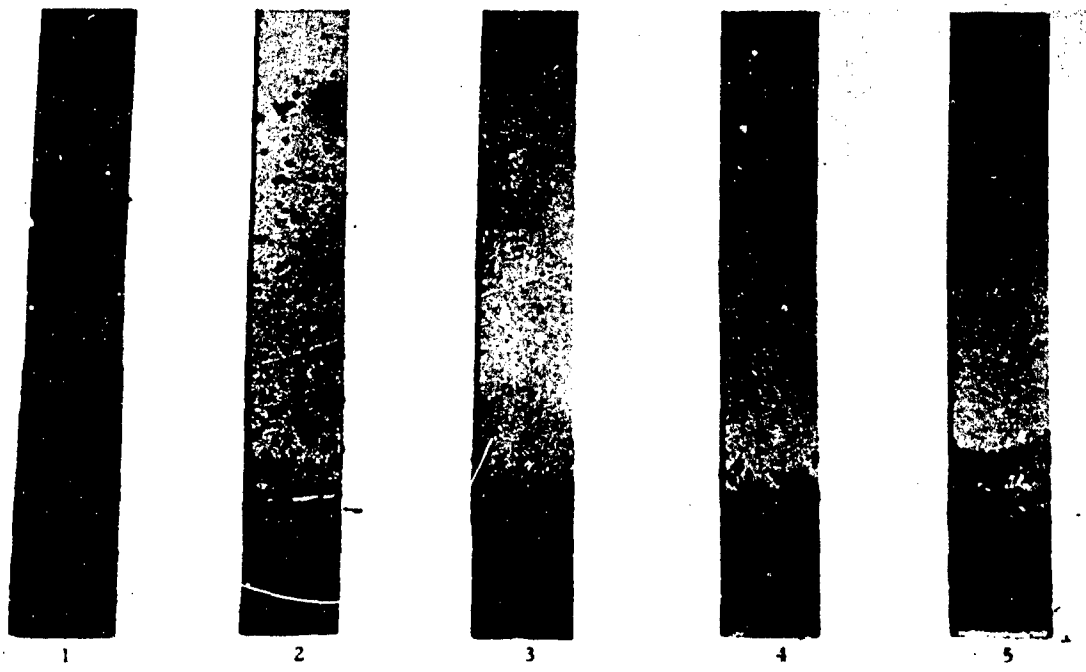


FIGURE 8. CLOSE-UP OF UPPER SURFACES OF STRIPS 1 THROUGH 5

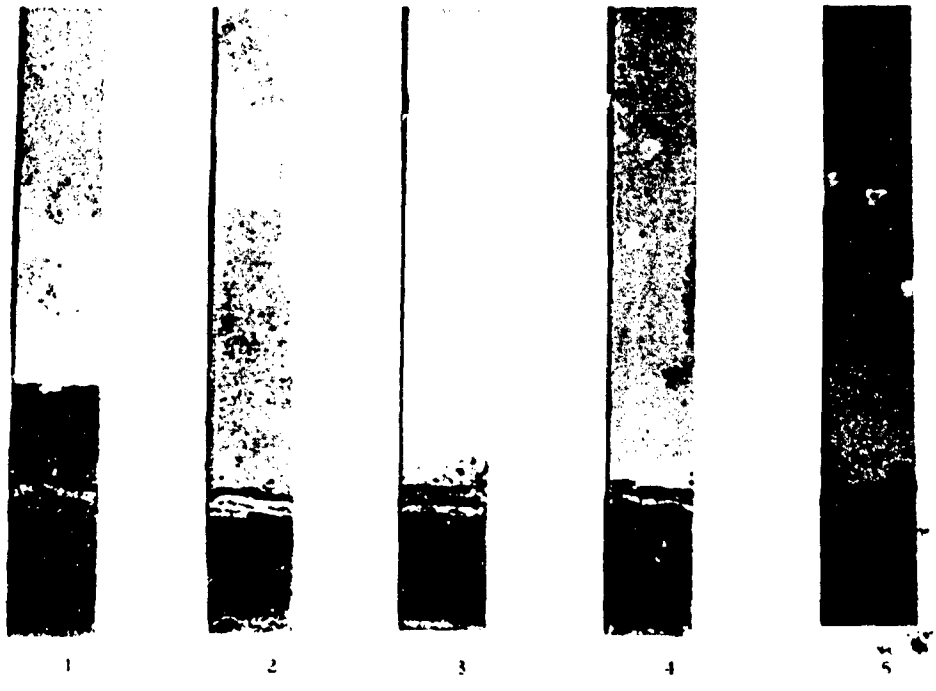


FIGURE 9. CLOSE-UP OF LOWER SURFACES OF STRIPS 1 THROUGH 5

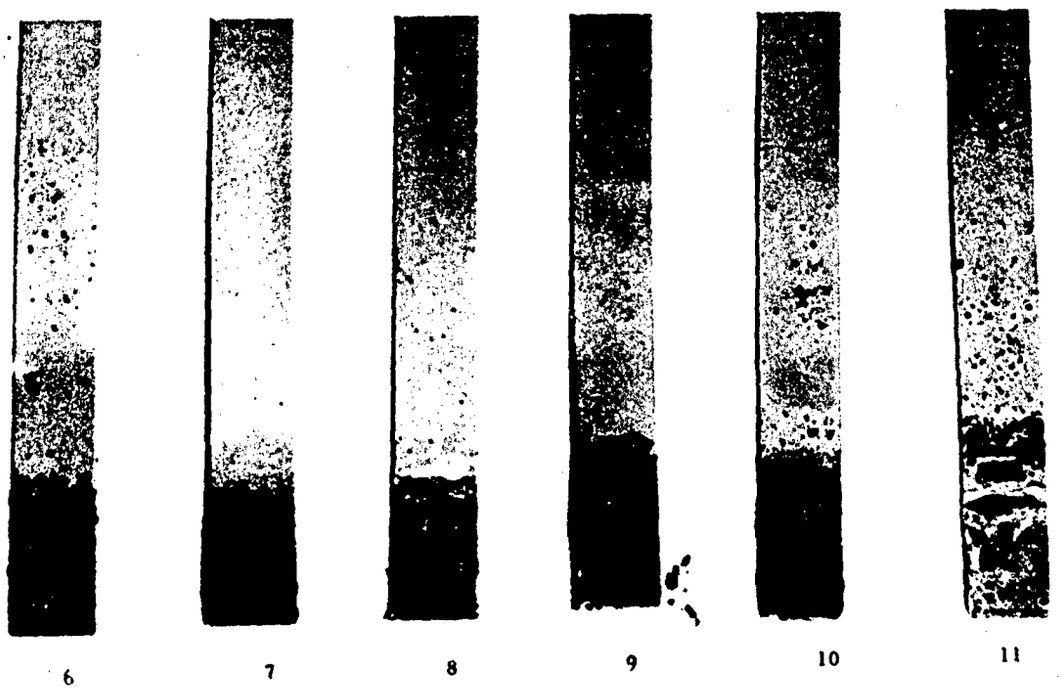


FIGURE 10. CLOSE-UP OF UPPER SURFACES OF STRIPS 6 THROUGH 11

FIGURE 11. CLOSE-UP OF LOWER SURFACES OF STRIPS 6 THROUGH 11

The deposits in the water-layer areas were all dark reddish-brown, and in several cases a white deposit was observed at the fuel-water interface, most pronounced on strips 2, 3, 4, 8, 10 and 11. Some dark brown to black, hard, varnish-like deposits were observed near the interface in some cases, particularly Nos. 11, 6, 5, and 4. Black tubercles up to 3/32" in diameter were observed on the upward-facing surfaces, mostly near the fuel-water and fuel-air interfaces.

On most of the steel strips, the heavily corroded area did not extend far above the water-fuel interface. However, two cases were clearly evident (Nos. 1 and 11) in which the corroded area extended an appreciable distance up into the fuel. This is quite evident in Figures 6-11. It is considered possible that the extension of the corroded area indicates microbial growth proceeding up the strip and carrying the corrosive environment with it. Interestingly, Drums 1 and 11 were the only two drums in this series containing neither methoxyethanol nor glycerin. Drum 1 had shown microbial populations of the 10^6 order, Drum 11 only 10^3.

After removing the loose deposits with a stiff nylon brush, the extent of corrosion was determined by thickness measurements and surface traces. The loss in thickness in the heavily corroded portions were as follows:

Strip No.	1	2	3	4	5	6	7	8	9	10	11
Loss, mils	3	6	3	7	1	3	1	4	5	6	6

The surface traces showed that the recession occurred rather abruptly at the water line on most of the strips.

The four-strip assemblies were removed from the drums, the bolts were removed from the lower ends, and the strips were spread out for examination and photographing without disturbing the deposits. In the photographs (Figs. 12-15), the two inner strips are the bare metals (the iron the darker colored), and the two outer strips are the coated steel (the epoxy the darker colored). After disassembly, the strips were brushed to remove deposits, thickness measurements were made, and the coatings were examined for adhesion.

The bare steel strips of the assemblies were quite similar to those in the single-strip drums, except that here the strips had been "on edge" and both faces were corroded more or less the same. Thickness measurements on the water-phase areas indicated losses of 2 to 5 mils:

Strip No.	1S	2S	3S	4S	5S	6S	7S	8S	9S
Loss, mils	3	2	4	2	5	3	2	5	3

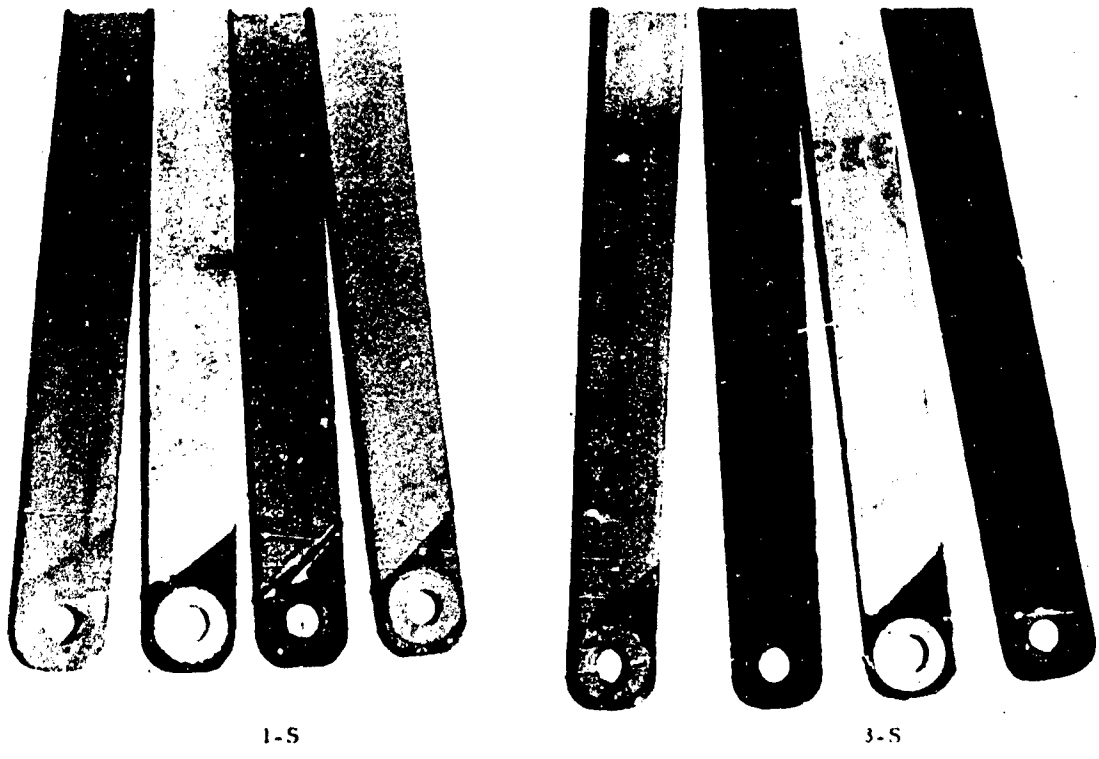


FIGURE 12. SPECIMEN ASSEMBLIES 1S AND 3S

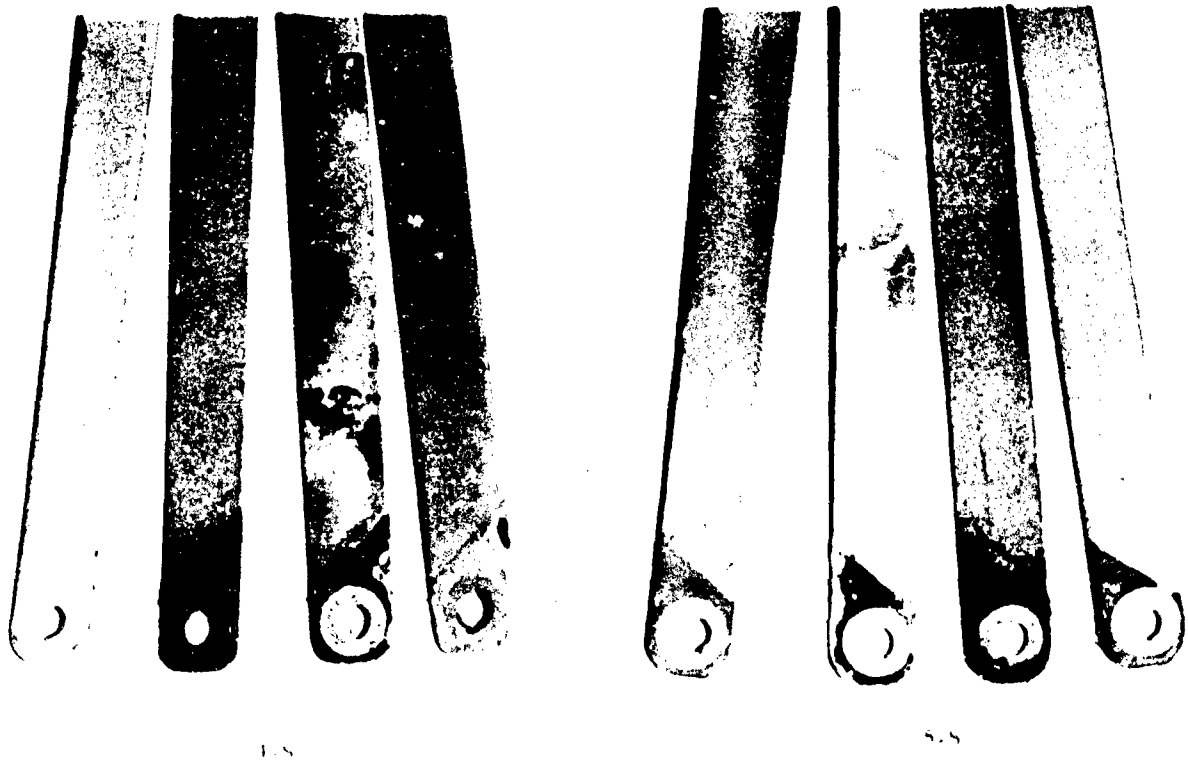
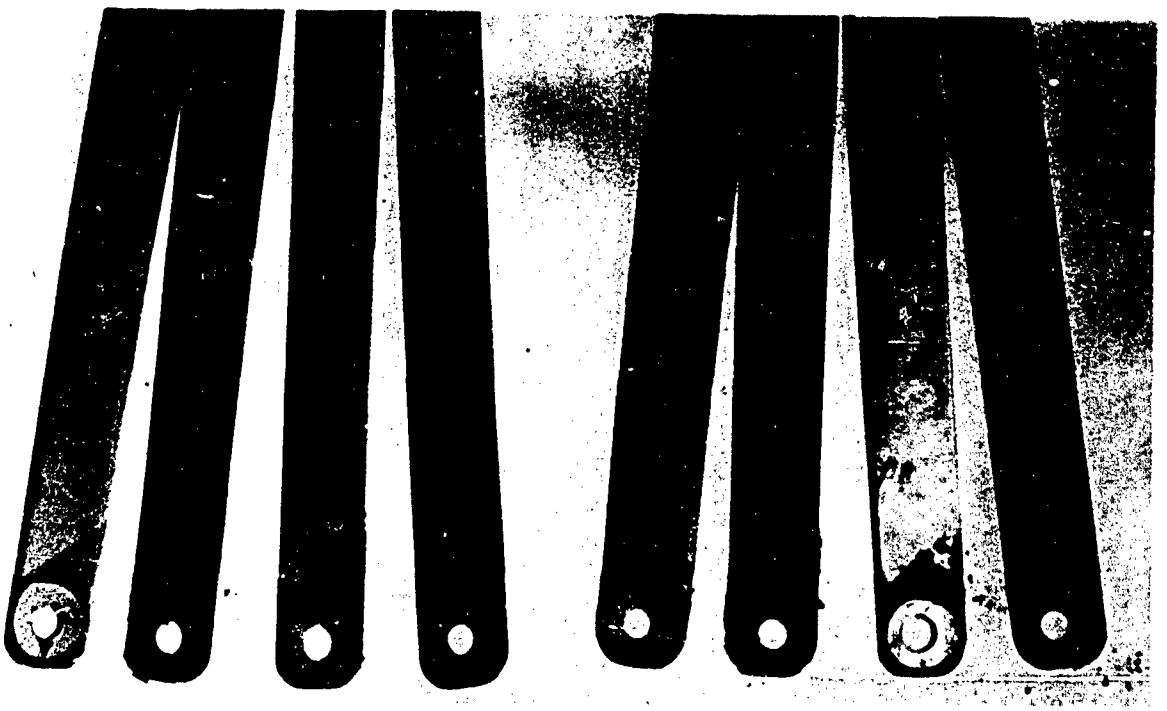
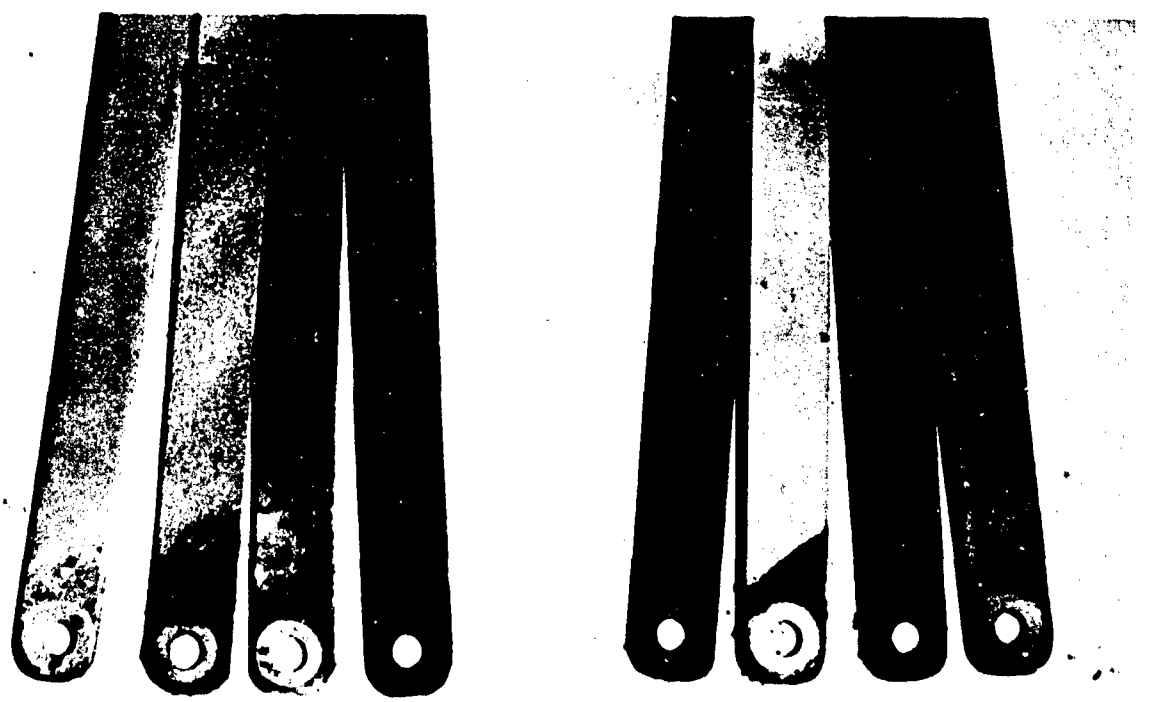


FIGURE 13. SPECIMEN ASSEMBLIES 4S AND 5S



6-S 7-S

FIGURE 14. SPECIMEN ASSEMBLIES 6S AND 7S



8-S 9-S

FIGURE 15. SPECIMEN ASSEMBLIES 8S AND 9S

There was no correlation between the extent of attack and the microbial population.

The bare aluminum strips suffered very little corrosive damage; some light etching was observed. On some of the specimens this was more severe under the Teflon washers. No pitting or exfoliation was noted. As the aluminum surfaces were put into test in the "as-received" condition, more precise observations could not be made. The water-layer areas were usually covered with red or brown deposits.

Neither the epoxy nor the furan coating deteriorated seriously in these tests. Both coatings remained pliable, and there was no evidence of cracking, peeling, or blistering. In the water-exposed areas, the furan showed some loss of adhesion: This section could be peeled with a knife point, removing the total coating in pieces about 1/4" X 1/2" and exposing bare uncorroded metal. The epoxy did not show any loss of adhesion as measured by this rough qualitative test. In the water-exposed area, each of the coatings was overlaid with reddish or brownish deposits.

All of the specimen assemblies followed this general pattern, and differences were so slight that no specific comparisons could be made. The general conclusions to be drawn from examining the specimens is that the combination of dilute sea water and microbial growth will cause rapid corrosion of bare steel, but that the 5052 aluminum was not attacked severely during the 19 weeks of this test. The coatings did not appear to be harmed, except for possibly a slight loss of adhesion of the furan.

The epoxy interior coatings of the drums were not inspected closely, since it was desired to leave the drums and contents intact. So far as could be determined by inspection through the bungs, the coatings were unharmed.

VI. REVIEW OF APPLICABLE TECHNICAL ORDERS AND MANUALS

A. General

This section includes a listing of Air Force T.O.'s, manuals, and related documents that have been reviewed (see Table 32), as well as a discussion of this literature in relation to fuel contamination and quality control. This discussion relates primarily to fuel receipts by tank car and tank truck, aboveground bulk fuel storage, hydrant systems, large refueling vehicles, the refueling and defueling of large aircraft, and fuel sampling and analysis. Pipeline or marine operations are not discussed in detail, since these are covered only in a very general way in the literature. The obsolete AFM 67-14 and the current MIL-HDBK-201A, as well as AFM 85-16, contain information on pipeline and marine operations. Some additional information on quality control of pipeline shipments is given in T.O. 42B-1-1. Considerable information on marine and pipeline movement of fuel, and on quality control in general, is given in AFM 74-3, Petroleum Procurement Inspection Manual (MPSA). However, this manual refers primarily to fuel handling outside the individual Air Force base and hence is excluded from detailed consideration in this report.

Subjects omitted from this discussion are portable or air-transportable hydrant systems, hydraulically operated (aqua) fuel dispensing systems, drum-fuel operations, small fuel and oil servicing trucks, and small-scale pumping and dispensing systems. References to T.O.'s covering some of these subjects are given in Table 32.

The maintenance of permanently installed fuel systems is well covered in AFM 85-16, which is a good basic manual on the subject. There is no comparable document covering operation of permanently installed systems. Although MIL-HDBK-201A comes the closest to meeting this need, it is too general to serve as an operating guide. In the case of refueling vehicles, there is no document covering in detail operation or maintenance; these are covered by individual T.O.'s on each vehicle.

The basic guide for SAC fuel operations is SACM 67-2. Although some subjects are covered in detail (e.g., frequency and location of sampling), the manual does not furnish a complete operating guide.

Of the T.O.'s reviewed, special mention should be made of T.O. 37A9-3-1-101, covering operation and maintenance of hydrant systems,

TABLE 32. FUEL HANDLING DOCUMENTS REVIEWED

Document No.	Title	Date*
AFR 91-13	Permanently installed storage and dispensing facilities for petroleum and unconventional fuels	25 Feb 60
**AFM 67-14	Military fuels operation handbook (RESCINDED) (see MIL-HDBK-201A)	1 Nov 55
**AFM 74-3	Petroleum Procurement Inspection Manual with Supplement 1	30 Jun 58 10 Jul 63
AFM 85-16	Maintenance of permanently installed petroleum storage and dispensing system	20 May 64
**AFM 86-4	Standard facility requirements	1 Sep 61
SACM 67-2	Aviation fuels and propellants operations handbook (including changes through No. 1)	25 Jul 63
**MIL-HDBK-201A	Military standardization handbook - petroleum operations (an updated version of AFM 67-14)	12 May 61
Letter, MAMA MAOQ 64-1	Fuel contamination and preventive measures	3 Feb 64
Technical Order (T.O.) Numbers)		
0-1-36	Numerical index of technical publications: vehicles, construction and materials handling and associated publications (36 category)	7 Oct 63

* Date of latest issue or revision.

**Obtained on loan or reviewed at Base library. All documents not so marked have been obtained for retention.

TABLE 32. FUEL HANDLING DOCUMENTS REVIEWED (Cont'd)

T.O. No.	Title	Date*
0-1-37	Numerical index of technical publications: fuel, oil, propellant handling and associated equipment publications (37 category)	2 Oct 63
0-1-42	Numerical index of technical publications: chemical, oxygen, metal, textile, fuels, cordage, lumber and rubber materials (dopes, cleaning compounds, glues, gases, lubricants, paints, plastics, etc.) publications (42 category)	10 Jan 64
00-20L-1	Liquid fuel and oil storage and dispensing facilities inspection system	27 Nov 59
**00-25-172	Ground servicing of aircraft and repositioning of equipment	12 Dec 62
1B-52B-2-2	Ground handling, servicing, and air frame maintenance (USAF series B-52B, B-52C, B-52D, B-52E, and B-52F aircraft)	8 Nov 63
1B-52G-2-2	Ground handling, servicing, and airframe maintenance (USAF series B-52G and B-52H aircraft)	20 Nov 63
36A9-3-8-1	Type F-6 fuel servicing semitrailer (operation and service***)	30 Sep 63
36A9-3-8-535	Replacement of micronic filters with filter separators on fuel servicing semitrailer Type F-6	1 Apr 61 (Resc. 1 Apr 62)

* Date of latest issue or revision.

** Obtained on load or reviewed at base library. All documents not so marked have been obtained for retention.

***This series also includes -3 (overhaul instructions) and -4 (parts breakdown).

TABLE 32. FUEL HANDLING DOCUMENTS REVIEWED (Cont'd)

T.O. No.	Title	Date*
**36A9-3-9-1	Fuel servicing semitrailer, Type F-7 (Butler) (operation and service***)	15 Feb 61
36A9-3-13-1	Type MJ-1 fuel servicing semitrailer (Standard Steel Works) (operation and service***)	25 May 62
36A12-13-7-1	Fuel servicing, tank truck, Type AF/S32R-2 (Heil) (operation and service***)	3 Oct 63
36A12-13-8-1 and -1C	Aircraft refueling tank truck Type AF/S3R-2 (Consol. Diesel) (operation and service***)	24 May 63 28 Nov 63
36Y31-1-1	Removal of rust and sediment from fuel and oil servicing truck and trailer tanks and application of coating, interior, fuel and water resistant	27 Apr 62
37A-1-101	Fuel and oil handling equipment and mechanical fuel segregators	26 Jun 62‡
37A2-2-2-1	Fuel hose four-wheel trailer Type MH-1 (Barnes) (operation and service***)	29 Oct 59
37A2-2-3-1 (formerly 19-75AB series)	Fuel hose trailer, Type T-4 (Barnes) (operation and service***)	1 Aug 59
37A2-2-4-1	Filter-meter-hose fuel transfer trailer Type MH-2 (Pryor) (operation and service***)	15 May 60

* Date of latest issue or revision.

** Obtained on load or reviewed at Base library. All documents not so marked have been obtained for retention.

***These series also include -3(overhaul instructions) and -4 (parts breakdown).

‡ Current rewrite (Apr 64) not yet available for review.

TABLE 32. FUEL HANDLING DOCUMENTS REVIEWED (Cont'd)

T.O. No.	Title	Date*
37A2-2-4-11	Filter-meter-hose fuel transfer trailer Type MH-2 (Garsite) (operation and service***)	15 May 60
37A2-2-4-21	Trailer mounted aircraft fuel servicing unit, Type MH-2A and Model 2130 (Consolidated) (operation and service***)	2 Apr 63
37A8-2-3-3	Filter-separator (Briggs) (overhaul)	1 Mar 59
**37A9-1-506	Replacement of excelsior pack water separators and filter elements in permanently installed fuel storage and dispensing systems	27 Nov 59
37A9-1-506C	Ditto (extends rescission date to 27 Nov 63)	15 Oct 62
37A9-3-1-1	Criteria for flushing and purging of hydrant refueling systems	30 Jan 64
37A9-3-1-101	Hydrant fuel storage and dispensing systems (permanently installed)	30 Nov 59
37A9-3-2-1	Portable hydrant refueling system, Part No: 40000 (Amer. Pipe & Steel)	30 Jan 61
37A9-3-3-11	Air-transportable hydrant refueling system MPD-494 (Columbian)	1 Sep 60
37A9-5-1-101	Mechanical fuel storage and dispensing systems (permanently installed)	12 Jun 59
37A11-3-1	Type A-6 portable refueling unit (Yale & Towne)	1 May 61

* Date of latest issue or revision.

** Obtained on loan or reviewed at Base library. All documents not so marked have been obtained for retention.

***These series also include -13 or -23 (overhaul instructions) and -14 or -24 (parts breakdown).

TABLE 32. FUEL HANDLING DOCUMENTS REVIEWED (Cont'd)

T.O. No.	Title	Date*
37A11-4-1	Portable fuel dispensing pump unit Type B-1 (Gorman-Rupp)	1 Jul 60
37C2-2-2-503	Addition of drainage facilities to RP-1 fuel storage	28 May 62
40W6-3-1	Serv-a-jet hydrant fueling system servicing vehicle, Model No. BD600T-1, Part No. 13W70 (Bowser) (operation and service**)	27 Mar 62
40W6-3-11	Fueling and defueling system servicing vehicle Model MV-2, Part No. 15100 (Permanent Filter) (operation and service**)	7 Apr 61
42B-1-1	Quality control of fuels and lubricants	10 Feb 64
42B-1-16	Quality control of liquid propellants	2 Sep 57
42B1-1-1	Use and disposition of fuels	20 Dec 61
42B1-1-9	Elimination of water and ice from aviation fuels	5 Apr 63
42B1-1-13	Testing jet fuel at Air Force bases	10 Sep 62
42B7-2-1-1	Quality control of propellant unsymmetrical dimethylhydrazine + JP-4 (40% UDMH + 60% JP-4)	1 Jul 63
42B7-2-1-2	Quality control of rocket fuel, RP-1, Specification MIL-R-25576	15 Apr 63

* Date of latest issue or revision.

** These series also include -3 or -13 (overhaul instructions) and -4 or -14 (parts breakdown).

TABLE 32. FUEL HANDLING DOCUMENTS REVIEWED (Cont'd)

T.O. No.	Title	Date*
Unobtainable Documents		
36A9-3-1-1	Semitrailers, fuel servicing, Type F-2A, service and operation procedures for preventing ice formation in fuel (referenced in obsolete AFM 67-14; not listed in current indexes)	Unknown
36A9-3-1-517 and 517A	Inspection of pumping system and replacement of filter elements on fuel servicing semitrailers Types F-1A, -2A, -6, -7, MJ-1, MD-3 (Rescission date 19 Sep 61)	10 Jul 59 3 Jun 60
42B-1-15	Petroleum handling operations (TM 10-1101, including Chg 1, 2, 3, 4) (Army publication; no longer printed)	14 Sep 55

*Date of latest issue or revision.

since this is the nearest thing to a "complete" document on this subject. Another document of particular interest is T.O. 37A-1-101, which covers specific items of fuel handling equipment such as hoses, nozzles, strainers, and water segregators, and also includes a considerable amount of miscellaneous information pertinent to fuel contamination problems. This T.O. has not been entirely modernized; e.g., it refers entirely to micronic filters rather than filter-separators*. The information on refueling vehicles is contained in individual 36-series T.O.'s applicable to the particular units; hose carts (including those with filter-separators) are covered by 37-series T.O.'s and one group of 40-series T.O.'s. Information on fuel quality control and testing is included in 42-series T.O.'s.

As would be expected from the large number of documents involved, numerous contradictions exist in procedures and criteria. There are also significant omissions. The discussion that follows is directed at the various aspects of fuel handling as they affect the fuel contamination picture, with particular attention given to conflicts and omissions in the literature.

B. Incoming Fuel Shipments

1. Sampling and Water Gaging

Conflicting instructions exist on the methods of sampling incoming shipments, and there is some confusion on methods of water gaging and removal:

SACM 67-2, Par. 18a requires a bottom level sample (no details on sampling method) to be taken from at least one tank car, tank truck, barge, tanker, and/or pipeline receipt for each grade of fuel received during each day; these are to be checked for color, specific gravity, and visible water and solids, and then forwarded to the base laboratory for testing.

T.O. 42B-1-1, Par. 4-6 (tank cars and tank trucks): "... Sample through the top hatch into a clear, clean glass bottle; examine for color, water, and sediment. ... When all tests and examinations are satisfactory, unload into base storage after minimum settling time has elapsed." (Minimum settling time is not specified.)

T.O. 37A-1-101, Par. 822 describes the use of water gage paste for tank gaging and then states: "Shipments of fuel in tank cars, tank trucks, trailers, etc., will be water tested on receipt. When water

*It is understood that a new version of T.O. 37A-1-101 is being issued in April 1964, but this was not available for review.

is detected, it will be removed by pumping or draining... Water removed from fuel systems, tanks, or containers will not be discharged through sewage systems."

T.O. 37A9-3-1-101 states that incoming tank cars and tank trucks are to be checked with water gage paste, but does not suggest any procedure to follow in case water is detected.

MAMA letter (MAOQ 64-1) states that "checks for and removal of water prior to unloading cargoes into the fixed system must be made."

T.O. 42B1-1-9, Par. 1-10: "The effect of water and ice in aircraft fuels can be minimized during each phase of the base fuel handling operation by rigid adherence to the following: (a) Incoming fuel shipments will be checked for water-free content prior to acceptance. (b) If at all possible, bulk shipments will be allowed to stand unagitated for a period of one hour per foot of depth of storage container prior to testing for water. This allows settling of entrained water resulting from movement and agitation of the fuel during transit. A minimum three-hour settling period should be maintained. (c) Accepted shipments (after water test and drain) will be transferred to base storage facilities." The specified settling periods would seem to be intended for all types of transit, but it is obviously impractical to let tank trucks stand three hours before unloading under existing delivery schedules at most bases.

From the foregoing, it is evident that some confusion exists on water gaging and sampling of tank cars and tank trucks. Although water gaging each shipment is desirable, it could involve too much delay in unloading when delivery schedules are heavy or unloading facilities limited, particularly if compartmented tank cars or trucks are involved. A more feasible procedure might be a drain or manifold draw of sufficient fuel to check for the presence of gross amounts of water; if more than a pint or so appeared, the draw and check could be repeated. Even if applied to each compartment, this should not be prohibitively time-consuming. If large amounts of fuel had to be drawn to clear the manifold, disposal facilities might be required, depending on local fire regulations. In any case, it does seem quite important to have some quick-check method for water detection, rather than relying exclusively on source inspection.

Frequent reference is made to the use of three or four pounds of calcium chloride for thawing frozen outlet pipes and valves on a tank car or truck, in the event that heating equipment is not available (AFM 85-16,

T.O. 42B1-1-9, and 37A9-3-1-101). If widely practiced in cold climates, it would be expected that significant amount of chloride would be introduced into the fuel systems.

2. Strainers in Unloading System

Strainers in the fill plugs (unloading couplings) are usually specified as 40 mesh and the line strainers as 80 mesh. Discrepancies exist in the inspection and cleaning schedule:

	Frequency of Inspection and Cleaning	
	Fill-Plug Strainers	Unloading-Line Strainers
AFM 85-16	After each unloading	After each unloading
T.O. 37A9-3-1-101	Before each unloading	After each unloading
T.O. 37A9-5-1-101	Before each unloading	After each unloading
T.O. 42B-1-1	Once a day, as specified in T.O. 37A-1-101	
T.O. 37A-1-101	After each unloading	At least weekly

The weekly requirement for inspection and cleaning of line strainers is more in line with existing practice, as it is entirely impractical to perform this operation after every transfer from a tank car or tank truck.

C. Fuel Storage Tanks

1. General

This section includes information on both aboveground bulk storage tanks and underground operating storage tanks, as the contamination problems are interrelated and somewhat similar. Most of the pertinent information on bulk storage tanks pertains to floating-roof tanks, which are the predominant type in JP-4 storage.

2. Dykes and Surface Drainage

As specified in AFM 85-16, T.O. 37A9-3-1-101, and 37A9-5-1-101, earthen dykes for aboveground tanks require a capacity equal to the tank contents plus a 12-inch freeboard. Water is drained from the dyke area by a ditch and drain line, at least 6-inch, with a gate valve that is normally locked in closed position.

3. Floating-Roof Tanks

Various types of floating-roof seals are discussed in AFM 85-16, and it is mentioned that two of the newer types illustrated, with synthetic rubber seals, offer better protection against the elements and against the loss of petroleum vapors. In view of the importance of excluding water from stored JP-4 fuel, it would appear desirable to develop definite specifications or recommendations for types of seals to be used in new installations and in modification of existing tanks.

Several documents (AFM 85-16, T.O. 42B1-1-9, T.O. 37A9-1-101, and T.O. 37A9-5-1-101) refer to the use of calcium chloride to free up frozen roof seal rings. If widely practiced in cold climates, it would be expected that considerable amount of chloride would enter into the water bottoms.

The three types of roof drains for floating-roof tanks - open drains, siphon drains, and pipe drains - are described in a very general way in T.O. 37A9-3-1-101 and with even less detail in T.O. 37A9-5-1-101; there is no discussion of the types of roof drains in AFM 85-16. Nowhere has there been found any mention of the fact that closed drains (pipe drains) are preferable in that they minimize the amount of rain water entering the tank. The distinction between flexible hose and jointed pipe (swing-line) roof drains is not made clear, although the type of drain may be of importance in deciding whether the roof drain foot valve should be left normally open or closed. It is stated in AFM 85-16 (Par. 112b) and implied in T.O. 37A9-3-1-101 (Par. 4-29) that the foot valve should be opened only after each rain or thaw. Further, SACM 67-2 (Par. 39d) states that roof drains should be kept closed, drained, and plugged (at top entry) during periods when freezing temperatures occur, except when actually draining water. In practice, it is understood that many bases guard against freezeup by the use of ethylene glycol in the roof drain, thus eliminating the need for the top plug. This practice is not mentioned in any of the documents reviewed. The question of whether to leave the foot valve open or closed during warm weather is apparently rather controversial. Keeping the valve closed is a safeguard against loss of tank contents in the event of a ruptured or defective drain line. On the other hand, keeping this valve closed has led to at least one case of roof damage during a cloudburst at a commercial terminal; possibly the emergency drains were inoperative or absent in this particular case. This whole question should receive some discussion in the applicable T.O.'s and manuals, even if firm recommendations are not feasible.

4. Tank Inspection and Cleaning

In the past, bulk and operating storage tanks were on a nominal 3-year inspection schedule with cleaning "as needed"; the 3-year periods were often overrun by a year or two. More recently, the 3-year inspections have been performed quite regularly, and some bases specify tank cleaning at each 3-year inspection regardless of condition. The situation as given in the applicable documents is somewhat confusing; particularly since "inspection" may mean either entry or nonentry.

AFR 91-13: "Bulk liquid fuels storage tanks with an individual capacity of 500 barrels or more, and tankage of smaller individual capacity having manway openings, will be inspected internally for deterioration on a scheduled 3-year recurrent basis. If necessary, tanks will be cleaned after this inspection."

AFM 85-16, Par. 35a(2) gives the same 3-year schedule for aboveground tanks, but Par. 35b(2) for underground tanks requires only "interior surface inspection and maintenance for sludge and corrosion, and cleaning as required" - i.e., no fixed schedule. To compound this confusion, this manual further states (Par. 112) that the 3-year schedule applies to both aboveground and underground tanks, and continues: "Visual inspections may be made from access covers and manholes with samples taken to determine the amount of sludge at the bottom of tank. ... If strainers downstream from a tank indicate a considerable amount of sludge coming through, the tank should be cleaned immediately."

Among the T.O.'s reviewed, only three had anything on tank cleaning and inspection. T.O. 37A9-3-1-101 and T.O. 37A9-5-1-101 merely reference AFM 85-16. T.O. 42B-1-1, Par. 5-10 merely calls for inspection "when the need is clearly indicated" and cleaning "when necessary"; reference is made to AFM 85-16 and AFR 91-13. However, this same T.O. in Par. 4-45 cites the 3-year requirement, as follows*: "AFR 91-13 requires that storage tanks be inspected once every 3 years for deterioration or contamination and be cleaned if necessary after this inspection. Operating storage tanks, because of their proximity to the aircraft in the dispensing system, should be opened at least once every year and inspected for buildup of rust and sludge on tank bottoms, ladders, and sides of the tanks. This type of inspection can be performed through manhole openings without physical entry whenever tanks have been pumped down to remove all product possible.

*This material cited from T.O. 42B-1-1 also appears in MAMA letter MAOQ 64-1.

Sludge deposits in excess of one-half inch in depth in an operating storage tank indicate a need for cleaning."

Summarizing the foregoing material, it appears that AFR 91-13 requires internal inspection (presumably with entry) on all "bulk" storage tanks of at least 21,000 gallons capacity; this should be clarified if it was the intent to include underground operating tanks in this category. The information in AFM 85-16 and the T.O.'s that were reviewed is either vague or contradictory. There is no clear-cut statement of inspection and cleaning schedule for underground operating tanks. In the MAMA letter and in T.O. 42B-1-1, a 3-year inspection schedule is taken for granted, and a 1-year schedule is recommended for operating storage tanks. These references gave a criterion of one-half inch (1/2") of sludge buildup in operating storage tanks as an indication of the need for cleaning. No mention has been found anywhere of such a criterion for cleaning bulk storage tanks. It is quite probable that the current inspection and cleaning schedules are being fixed by special orders or communications that were not available for this review.

5. Settling, Gaging, and Removal of Water

Some years ago it was common practice to carry water bottoms of 4 to 10 inches in bulk storage tanks to prevent loss of fuel through leaks in the tank bottom. Currently, in the case of JP-4, heavy emphasis is placed on removal of water from all storage tanks, but the instructions on how this is to be accomplished are in many cases incomplete or contradictory, as illustrated by the following excerpts.

AFM 85-16, Par. 33: "Water bottoms are not permitted in petroleum storage tanks, especially those containing JP-4. Water with entrained air rising through the fuel tends to generate and accumulate a static electric charge. Whenever feasible, existing tanks that do not have provisions for daily water elimination should be modified to incorporate a low point or sump to accumulate water settling out of the fuel and a drain valve or portable pump for daily water removal."

SACM 67-2 specifies that water content of operating storage tanks is to be gaged daily, and also after each refilling operation. On account of bacterial growth, the water level is to be maintained at one-quarter inch (1/4") or less. Bulk storage tanks are to be allowed to settle at least 4 hours before transferring fuel to hydrant system.

T.O. 42B-1-1, Par. 5-13: "...aircraft fuel received into bulk storage should be permitted to stand undisturbed for a period of 1 hour per

foot of depth of storage tank. Where this is not possible, a minimum 3-hour settling period should be maintained. ... After transfer of product to intermediate or operating tanks, it is desirable to allow a settling time of at least 3 hours if conditions permit, prior to dispensing to hydrants and fuel servicing units." Par. 4-10: "After receipt of pipeline movement or tank transfer, the storage tank will be allowed to settle for a minimum of 3 hours. A low-level one-quart sample (in the vicinity of the discharge line) will then be taken in a clear glass one-quart bottle and visually observed for appearance, water and sediment. If sample is not clear, the additional settling time will be required prior to dispensing fuel to hydrants and servicing units." (Note: Apparently Par. 4-10 does not apply to receipts by tank car, truck, barge, or tanker.)

T.O. 42B1-1-9, Sec. II: "Fuel storage tanks should be checked with water-test paste daily and after the receipt of each load of fuel during normal weather. If possible, the fuel should be allowed to settle 3 hours prior to checking for water. This settling period will insure a more accurate test than would be possible immediately after the receipt of the fuel. Underground fuel tanks should be checked more frequently during periods of heavy rain, melting snow, or high ground-water level. Any water detected in underground tanks must be immediately removed by use of a small rotary or piston type 'thief pump.' Aboveground tanks should be provided with a water draw-off valve in the bottom of the tank. Since aboveground storage tanks are subjected to greater variations in temperature than underground tanks, condensation will take place at correspondingly greater rates. Most of the entrained water will settle out if the fuel is allowed to remain unagitated for a period of 24 hours. Tanks which test consistently water-free are not normal. In such instances, it is possible that the suction pipe terminates too close to the bottom of the tanks, and, as fast as water accumulates it is drawr off with the fuel. The suction lines of underground storage tanks should be equipped with water-locking foot valves, floating suctions, discharge shut-off valves, or other devices designed to prevent free water from being serviced into aircraft, should it suddenly build up to dangerous levels, as might occur through a broken fill line. ..."

MAMA letter (MAOQ 64-1)*: "Present instructions state that the settling time required be a <u>minimum</u> of one hour per foot of tank depth. A visual sample check should be made to verify that the settling period has been long enough in each case. Schedules governing tank usage should provide the maximum settling time. Settling periods should be provided each

*Much of this information also appears in the current version of T.O. 42B-1-1.

time product is transferred to reduce the load placed on downstream filtration equipment. Industry has recognized the importance of adequate settling time by providing sufficient tank storage in system planning. Industry also has widely adopted the use of floating suctions in the transfer of jet fuel. The fact that floating suctions have not been installed at most AF bases further stresses the need for maximum settling of product prior to issue. . . . Daily checks for water should be made at both bulk and operating storage tanks. If there are accumulations of water, it should be removed. Hand pumps or small jet type pumps have been used to remove water from operating storage tanks to within 1/4 of an inch of the bottom. Purging procedures have been outlined in the revised publication of T.O. 37A9-3-1-1 for the removal of water and sediment through the drain valves installed at the low points on the system. The drain valves should be operated once a week when the system is in operation or under pressure. Collection and examination of a sample of the water from the water drawoff on aboveground storage tanks; at the interface area or water bottoms of operating storage tanks; and from filter/separator drains, will assist in indicating possible contamination."

Summarizing the foregoing material, it is seen that current instructions call for a minimum settling time in bulk storage tanks of 3 hours (T.O.'s) or 4 hours (SACM 67-2), with a recommendation for 1 hr/ft or even 2 hr/ft. It is fairly evident that 1 hr/ft, which would correspond to 30 to 40 hours of settling in large tanks, is completely impractical in bases with limited bulk storage capacity; in many cases, even 3 to 4 hours cannot by achieved regularly. With regard to gaging and removal of water from operating storage tanks, there is general agreement that a level of one-quarter inch (1/4") or less can be maintained, but there is no discussion of the problem with tanks that were installed level and may have shifted so that the gaging hatch is now at the high end of the tank. The water gaging of operating tanks "daily and also after each refilling operating" (SACM 67-2) appears to be more often than would be normally feasible or necessary. The same comment applies even more to this schedule as quoted in T.O. 42B1-1-9, which presumably refers to bulk storage tanks as well; it would be out of the question to let these tanks settle for water gaging after each tank car or tank truck is unloaded. The question of irregular bottoms in bulk storage tanks is not mentioned at all in the literature that was reviewed, and, correspondingly, there is no mention made of the allowable water level in such tanks. Also, the requirement for daily check and draining of water from bulk storage tanks, which is stated in the MAO letter, does not appear to be reflected in the T.O. and manual literature. Although it is obviously impossible to establish a single criterion for water level in tanks of widely differing configuration (bottom irregularity and placement of fuel pumping

lines and water drawoff line) it does appear that this question merits more than passing mention. If possible, some suggestions for sump design and configuration of tank bottom and fuel water lines should be incorporated in applicable manuals and T.O.'s and made mandatory for new installations. Possibly some criteria could be set up for sump installation whenever a tank is opened for inspection.

The question of floating suction lines receives only passing mention in the T.O.'s and manuals, and in fact the whole question of placement of suction and discharge lines does not receive much coverage. Nothing at all has been found relevant to lines in bulk storage tanks, and it seems to be common practice to use straight-in horizontal suction and discharge lines. For operating storage tanks, the general configuration of the tank fill line and the refueling pump suction are given in T.O. 37A9-3-1-101 and T.O. 37A9-5-1-101. The fill branch connection is a 6-inch pipe extending down to within 6 inches of the bottom of the tank, where it is fitted with a splash deflector. The pump intake has a baffle plate to prevent direct draw of water or sediment from the tank bottom. These configurations are presumably standardized by drawings of the standard Panero- and Pritchard-system tanks, but in some cases it is known that other configurations are used, such as fill lines with closed ends and slotted sides.

Another factor in the access of water to underground tanks is the location of the manhole cover. It appears to be common practice to bury these covers, although this introduces some danger of ground water entry through a defective flange or gasket. No specific prohibition against burying the manhole covers has been found in the literature. In the case of existing installations in which the covers are already below grade level, it would appear advisable either to provide extensions to the hatches so as to bring the covers above grade, or to furnish a sump around the hatch with provision for water drainage or pump-off.

6. Sampling and Analysis of Bulk-Storage Fuel

So far as can be determined, only yearly sampling is required by existing orders*; this is specified by T.O. 42B-1-1 Sec V for dormant storage stocks, and by SACM 67-2 for all fuel in bulk storage, whether dormant or not. Samples from such storage are submitted to Area laboratories for analysis. It would seem to be of some value to examine the contents of bulk storage tanks at regular daily or weekly intervals, if only visually, to determine whether the fuel is remaining reasonably clean and

*But MAMA letter MAOQ 64-1 recommends daily sampling.

light-colored, and to obtain some idea of how much the tank bottoms are being stirred up by fuel transfer operations. This relates to the over-all sampling for quality control, which will be discussed in somewhat more detail in a later section.

7. Fuel Storage Capacity

This subject is covered in AFM 86-4 Pars. 121-122, for peacetime and war reserve requirements, but reference must be made to various other documents to compute the required tankage for any given base. The number of days of storage authorized for each type of mission is covered in the USAF Material Program Guidance. Presumably this refers to total capacity including both bulk and operating storage, although this is not clear from the statements in AFM 86-4. In a previous section of this manual (Pars. 35-36), it is stated that each "standard hydrant fueling system" includes operational storage of 100,000 gallons per system in addition to the bulk storage. The number of hydrant systems and outlets required (in relation to the number of aircraft) are also defined in this section. Further information on the components required in hydrant systems are found in T.O. 37A9-3-1-101, Pars. 4-3 through 4-6. This information is listed here for reference only, as it has not been feasible to make a detailed comparison of how the bulk and operational storage capacities of individual Air Force bases match up with the stated requirements. The opinion has been expressed by fuels personnel of certain Air Force bases that their storage capacity was insufficient to meet their needs, and it was observed that difficulty was encountered at both bases in meeting the 4-hour minimun settling time in bulk storage tanks. In the scheduling of operating storage tank receipts and issues, it appears that little if any control is exercised over settling time. It is evident that a rather detailed study at a large number of bases would be required before realistic and enforceable requirements could be laid down for settling periods in storage tanks.

D. Hydrant Systems

1. General

The standard requirements for hydrant systems are given in AFM 96-4, Par. 36: "Hydrant fueling systems provide all necessary devices, controls, and equipment required to pump fuel from operational storage tanks and to deliver clean dry fuel to hydrant dispensing outlets in the apron. Each standard hydrant fueling system includes operational storage of 100,000 gallons per system in addition to the bulk storage and is capable of delivering 600 gpm at any single outlet of the system. ... Hydrant system requirements and outlet requirements for various missions" [are as follows]:

Mission Type	Hydrant Systems Required	Outlets Required
Heavy Bombers ZI and O/S	1 for ea 5 A/C	1 per aircraft
Medium Bombers ZI and O/S (and KC-97)	1 for ea 4 A/C	1 per aircraft
Tankers ZI and O/S (KC-135)	1 for ea 5 A/C	1 per aircraft
Medium Transports (Troop Carrier)	1 for ea 8 A/C	1 per aircraft
Medium Transports (MATS/AFLC)	1 for ea 8 A/C	1 per loading pt
Heavy Transports (Troop Carrier)	1 for ea 4 A/C	1 per aircraft
Heavy Transports (MATS/AFLC)	1 for ea 4 A/C	1 per loading pt
Nonassigned A/C (MATS/AFLC)	1 for ea 240 to 1800 scheduled flights per month	1 per loading pt

The following requirements are given for standard hydrant systems in T.O. 37A9-3-1-101, Pars. 4-3 through 4-6:

	Fighters	Transport & Troop Carriers	Medium and Heavy Bombers
Per filter-meter pit or hydrant lateral control pit:			
Operating tanks (no. & gal)	2 X 25,000 or 1 X 25,000	2 X 50,000	1 X 50,000
Deep-well pumps (no. & gpm)	2 X 300 or 1 X 600	2 X 300	1 X 600
Water separator	2 X 300 or 1 X 600	1 X 600	1 X 600
Filter-meter pit contains:			
Filter (no. & gpm)	1 X 600	1 X 600	1 X 600
Fuel-defuel valves (no.)	3	1	1
Meters (no. & gpm)	3 X 600	1 X 600	1 X 600
Piping to hydrant outlets (no.)	3	1	1

This information refers primarily to systems installed prior to 1955 (Panero). The water separators on the operating tanks were originally "hay-pack" type, but by now have presumably all been converted to filter-separators. Each filter-meter pit contains a micronic filter and meter, and also a fueling-defueling control valve. Systems installed since 1955 (Pritchard) use the same basic pumphouse arrangement as the earlier systems

(tanks, pumps, and filter-separators), but the filter-meter pits have been replaced by hydrant lateral control pits, each containing a defueling pump and (usually) separate fueling and defueling control valves. The final filtration and metering function has been moved to hose carts at the aircraft. Some hydrant systems will use one certain tank for receiving defuel; other systems are arranged to defuel into any tank desired.

Most of the components of hydrant systems (tanks, filter-separators, filters) are discussed in other sections of this report.

2. Hydrant Defueling

Fuel removed from aircraft is normally collected in an underground operating storage tank, which may be one tank reserved for this purpose or a tank chosen at random. The fuel actually removed from aircraft in defueling operations will be commingled with fuel returned to the defuel tank owing to pressure surges during refueling operations. This latter returned fuel will have just passed through the fixed filter-separator on its way from the refueling tank to the hydrant, and is presumably clean. The fuel returned from aircraft may be contaminated to varying degrees, depending on the condition of the aircraft tanks and the method of defueling. When defueling is accomplished through a hose cart in the Pritchard system, it appears that the fuel must pass through the filter-separator on the hose cart before it enters the hydrant and thence to the defueling header and defuel tank. At least, the T.O.'s on the MH-2, MH-2A, MV-2, and R-4 hose carts clearly indicate normal flow through the filter-separator during defueling. This question is raised here because of some disagreement on the part of operating personnel on whether or not the filter-separator is bypassed. Assuming that these hose carts are as shown in the respective T.O.'s, then it appears that only clean fuel should reach the Pritchard defuel tank. However, Panero-system defueling by gravity will permit unfiltered fuel to reach the defuel tank, as the micronic filter in the filter-meter pit is bypassed.

When defueling of aircraft is accomplished using servicing trucks or trailers, it appears that in all cases the fuel can be filtered either during the defueling or during transfer to bulk or operating storage. It is not known how widely such filtration is practiced.

So far as any general directive on handling of defuel, only T.O. 42B1-1-1, Par. 5-31, can be cited: "Fuel removed from the tanks of aircraft, other than aircraft which have been in storage, will be returned to the fuel dispensing system or servicing equipment used for that specification grade unless such fuel is indicated to be unfit for further use in aircraft. Fuel drained from aircraft which have been in storage, and fuel that

is contaminated or suspected of being contaminated will be withheld from use until complete tests have been conducted to establish useability." Filtration of defuel does not appear to be required before it is dumped into the operating storage (defuel) tank. Since there is not organized sampling program on defuel, it appears difficult to detect even seriously contaminnated fuel. At any base with extensive defueling operations, the admission of unfiltered defuel to operating storage tanks would appear to be an excellent means of introducing microbial contamination and in some cases salt water into these tanks. This is particularly true if the planes being defueled have come from bases all over the world.

3. Hydrant Flushing

Flushing of hydrant outlets is covered in the general hydrant system T.O. 37A9-3-1-101, Pars. 6-168 and 6-169: "After replacing the filter elements or making repairs that would permit the entry of foreign material between the filter and the hydrant, the hydrant shall be flushed. The hydrant shall also be flushed if it has not been used, or if it has been idle for a period of 14 days or more. Use an unrestricted flow in the normal direction and dispense 2000 gallons of fuel into a servicing vehicle. Fuel used for flushing may be dispensed through the servicing vehicle to aircraft, or it may be returned to the storage tanks."

T.O. 37A9-3-1-1 is concerned solely with flushing and purging of hydrant systems. The recent version of this T.O. (30 Jan 64) defines purging as the removal of water or sediment through a drain valve while the system is under operating pressure. Flushing is defined as movement of product through the system at maximum rate of flow; flushing is to be performed to remove contaminants that cannot be removed by purging, because drain valves have not been installed, or for one of the following reasons:

(1) System is idle for 30 calendar days (14 days in older T.O.).

(2) System is to be converted to dispense another grade of fuel.

(3) System is not and has not previously been used for servicing aircraft.

(4) Major maintenance has been performed (any maintenance or modification that could have resulted in entry of foreign material to the system).

According to this recent T.O., flushing is to be performed at maximum rate until visual inspection shows the fuel to be clean. Nothing is said about the quantity of flush required.

The purging of systems as defined in this T.O. is referenced in the letter MAOQ 64-1, where it is stated that systems should be purged by opening the drain valves weekly while the system is under pressure. T.O. 42B-1-1, Par 4-42 also recommends weekly purging.

A larger quantity of flush fuel, 6000 gal for 300 gpm units and 12,000 gal for 600 gpm units, is recommended in MAMA letter MAOQ 64-1. Here it is implied that the fuel is to be recirculated, i.e., returned to operating storage tanks.

4. Hydrant System Scheduling

The subject that is notably missing from the manual and T.O. literature on hydrant systems is any description of operating schedules - i.e., how to allow for maximum settling time after transfer from bulk to operating storage, what criteria must be observed for settling time of defuel before reservicing it to aircraft, etc. Obviously, these actual schedules will vary so much depending on the facilities and nature of operations of each individual base that no rigid criteria can be established. However, some general principles should be laid down to govern the over-all operation. In the actual operation of some Air Force bases, it has been observed that defuel received in an underground tank may be reserviced to an aircraft almost immediately. The whole problem of scheduling so as to permit some feasible settling time, both for defuel and for fuel received from bulk storage, should receive considerable attention.

A completely different approach to this problem would be keeping the operating storage tanks "clean," i.e., to admit only clean, water-free fuel from either bulk storage or from defueling operations and to provide tanks that are interior-coated or otherwise rustproofed. Such an approach would require a considerable revision of present facilities and operating methods, but might give significant improvement of fuel cleanliness.

E. Mobile Fuel Servicing Equipment

1. General

This section contains a discussion of the literature applicable to fuel servicing trucks and semitrailers and to hose carts. Only the larger servicing trucks and semitrailers have been reviewed. In the case of the

hose carts, the review has been confined to those units carrying filtering and metering equipment. The filter-separators used on all of these mobile fuel servicing units are discussed in more detail in Section VI-F.

2. Types of Mobile Fuel Servicing Units

Operation and service, overhaul, and parts lists for each type of servicing unit are covered in individual T. O. 's. The following is a brief summary of the major types of units used in large-scale fueling operations.

F-6 Fuel Servicing Semitrailer (Heil and Standard Steel). T. O. 36A9-3-8-1, -3, -4. Steel tank, 5000 gal. Pumping rate 600 gpm, with two 300-gpm filter-separators, Warner-Lewis VFCS-458-5K3 or -5K3-2. The F-6 originally had micronic filters; T. O. 36A9-3-8-535 (1 April 1961) covers replacement of the filters by filter-separators. According to the basic T. O. on this vehicle, the valving can be set for pumping (a) from tank to outside point, (b) from outside source, through meter and reels, to outside point, (c) from outside source directly into tank without filtering or metering, or (d) from outside to tank, with filtering and metering. Presumably the fuel is filtered under arrangements (a) and (b), although this is not brought out clearly.

MJ-1 Fuel Servicing Semitrailer (Standard Steel). T. O. 36A9-3-13-1, -3, -4. Aluminum tank, 5000 gal. Pumping rate 600 gpm, with one 600-gpm filter-separator Warner-Lewis VFCS-858-9K3 or -9K3-2. The MJ-1 originally had a 600-gpm micronic filter, but the basic T. O. has been modified to reflect the change to filter-separator. The MJ-1 can be used in defueling (par. 4-83), and the fuel is filtered and metered in such operation

R-2 Fuel Servicing Truck (Heil and Consolidated Diesel). T. O. 36A12-13-7-1, -3, and -4 (Heil); T. O. 36A12-13-8-1, -3, and -4 (CDEC). Aluminum tank, 5000 gal. Pumping rate 600 gpm, with one 600-gpm filter-separator. The Heil refueler uses a Warner-Lewis VFCS-1261-18K2 filter-separator, and the Consolidated Diesel a Briggs BFS-15-V-600 (CDEC Part No. 26192-1005). During defueling operations, in either the Heil or CDEC unit, the flow passes through the filter-separator in the normal direction.

F-7 Fuel Servicing Semitrailer (Butler). T. O. 36A9-3-9-1, -3, -4. Steel tank, 2500 gal. All of the material in the T. O. 's refers to micronic filters, and it is not known whether there are directives on the replacement of such filters by filter-separators.

MH-2 Filter-Meter-Hose Fuel Transfer Trailer. T. O. 37A2-2-4-1, -3, -4 (Pryor) and 37A2-2-4-11, -13, -14 (Garsite). Each of these

"hose carts" mounts one Warner-Lewis 600-gpm filter-separator, VFCS-1259-12K2. The flow diagrams in the T.O.'s for defueling operation show normal flow through the filter-separator and reverse flow through the meter.

MH-2A Trailer Mounted Aircraft Fuel Servicing Unit (Consolidated Diesel). T.O. 37A2-2-4-21 -23 -24 This unit is quite similar to the MH-2, and in fact is sometimes erroneously called an MH-2. According to the T.O.'s the MH-2A carries a 600-gpm Bowser filter-separator, Model 22W46 (CDEC Part 28887-1002). On the MH-2A CDEC units at several bases, it has been observed that the filter-separator was a Briggs BFS-11/10-V-600. It is not known whether this represents still another version of the MH-2A, or whether the Briggs and Bowser units are interchangeable. The flow diagram on the MH-2A appears to be similar to the MH-2.

MV-2 Fueling and Defueling System Servicing Vehicle (Permanent Filter). T.O. 40W6-3-11, -13, and -14. This "self-propelled hose cart" carries a 600-gpm Permadry Model 520-42 filter-separator with stainless steel shell. For defueling, flow is normal-direction through both filter-separator and meter. An interesting feature of this unit is the incorporation of a "look box" in the filter effluent line.

Serv-a-Jet Hydrant Fueling System Servicing Vehicle, Model No. BD600T-1 (Bowser). T.O. 40W6-3-1, -3, and -4. This is also a "self-propelled hose cart." It appears that this is the unit commonly termed the R-4 in SACM 67-2 and elsewhere, but the R-4 designation does not appear in the applicable T.O.'s. The Serv-a-Jet unit carries two 300-gpm filter-separators with aluminum shells. For defueling, flow is in normal direction through both filter-separators and meter. This unit, like the MV-2, has a "look box" in the filter effluent line.

3. Truck Fill Stands

Requirements for truck fill stands are spelled out clearly in AFM 86-4, Par. 40 (Basic Item 126-925, Liquid Fuel, Fill Stand, Truck): "... On all bases a maximum of 2 fill stands will be provided for each type or grade of fuel to be dispensed. These stands may be located in either the operating storage or the bulk storage areas. Fill stands will be single or double outlet per stand, with a capacity of 500 gpm per outlet. ... Wherever fill stands are installed for dispensing aviation engine fuels, one approved filter water separator, liquid fuel rate of 600 gpm, will be provided for each outlet." T.O. 37A9-3-1-101, which deals with hydrant systems in general, states that truck fill stands may be installed in bulk storage areas when specifically authorized by Hq USAF. It is stated (Par. 6-72 and 6-73) that "Basket type strainers of 100 mesh shall be installed in all truck fill stand

outlets, adjacent to and on the inlet side of the meters. The cross-sectional screen area of the strainer must not be less that 2.75 times the cross-sectional area of the outlet pipe of hose." T.O. 37A9-5-1-101, dealing with mechanical fuel storage and dispensing systems, gives similar requirements for strainers, except that the area is 2-1/2 times the size of the inlet line. This latter T.O. shows a micronic filter and water separator in each fill stand supply line.

4. Water Removal from Refueling Vehicles

Refueling trucks and semitrailers have one or another type of water segregator mounted on the bottom of the tank, as covered in some detail in T.O. 37A-1-101. In addition, certain units incorporate a water-lock valve to prevent drawing a slug of water into the pump. The removal of water from refueling vehicles, especially under cold-weather conditions, is discussed in some detail in T.O.'s and manuals:

T.O. 37A-1-101, Sec. V: "A refueling vehicle into which fuel has been transferred will be parked for a period of not less than 15 minutes after completion of transfer and prior to initial servicing of aircraft. This will allow sufficient time for water to settle on bottom of tank and be dispensed through segregator drain. ... In cold weather operations fuel and oil servicing vehicles will be parked outside of heated buildings to minimize ice or water formation caused by temperature and humidity differences between heated buildings and outside climatic conditions. The segregators will be drained of all water, and segregator sump drain will be used as a manual drain during freezing weather. Immediately after withdrawal of a servicing vehicle from a heated building, the water which has accumulated in the segregator bowl will be drained through the drain cock provided. The following will be accomplished to further preclude difficulties with segregator operation during extreme cold temperatures: Insure that fuel is passing through a 100-mesh strainer on transfer from a storage facility to the refueler... Fill tanks on refuelers as required and at the completion of each day's operation. Check segregator drains at truck fill stand each time the refueler is filled. Both the automatic drain and the segregator bowl drain should be checked. If drains are found to be frozen, thaw immediately (using heaters) ..."

T.O. 42B-1-9, Sec. III, contains essentially the same information, with additional comments on the desirability of keeping the refueler tanks full and allowing as much standing time as possible.

T.O. 42B-1-1, Par. 5-27: "After filling of the unit is completed, servicing of product therefrom will be withheld for at least 15 minutes to allow time for any water in the fuel to settle and to be discharged through the segregator drain. At this point, it is good practice to verify complete water removal by lowering a rod coated with water finding paste to the bottom of the refueling vehicle tanks. As an alternative, a sample may by taken from the bottom of each tank and visually examined for water. ... In low temperature regions, fuel should be "cold soaked" ... prior to servicing to aircraft, to facilitate separation of dissolved water from the fuel."

SACM 67-2, under "Daily Samples for Base Analysis," states: "Each time a refueling unit is filled, fuel will be allowed to settle for a minimum of 20 minutes. A sample will then be drawn from the segregator sump and visually checked for water and solids content. ... Segregator sumps will be drained and checked a minimum of once each day. In the event excessive water or solids are encountered, the unit will be withdrawn from service until the cause of the contamination can be determined."

Thus, there is general agreement that there should be a 15- to 20-minute settling period after loading a refueling vehicle and that the segregator should be checked and drained after this time.

It is interesting to note that a double check on segregator drains is mentioned in the Soviet literature*. This cites a settling period of 8 minutes after loading the refueler, after which the water bottoms are drained off and the refueler departs for the aircraft refueling operation. On arrival of the refueler at the aircraft, the drain is checked again; if any water is detected, the refueler stands another 15 minutes and rechecked for water. It is not known whether this really represents Soviet practice, but the double check is quite interesting. No mention of an extra check of refueler drains has been found in the U.S. manuals and T.O.'s; such a check might be of definite value.

5. Interior Tank Coatings for Refueling Vehicles

The interior coating of refueler tanks is covered by T.O. 36Y31-1-1, which describes the cleaning in some detail but leaves application details to be specified at the time of application of a given material. The coating materials must conform to MIL-C-4556 and also be approved by the WADC Materials Laboratory. The current MIL-C-4556B and QPL-4556-6 list three approved materials: Amercoat (epoxy), Thermoline (furan), and Zincilate (zinc).

*Ragozin, N.A., Reaktivnye Topliva [Jet Fuels], Gostoptekhizdat, Moscow, 1959, p. 89.

The use of interior coatings does not appear to be mandatory, although most Air Force refuelers with steel tanks have been interior-coated. The coatings are not suitable for aluminum tanks. The use of coatings on steel tanks is recommended in T.O. 42B-1-1, Par. 5-26.

6. Line Strainers in Refueling Vehicles

Daily inspection and cleaning of line strainers is specified in T.O. 42B-1-1, Par, 5-22. The inspection and cleaning procedures are given in T.O. 37A-1-101, Sec. IV. This latter T.O. also gives information on the "proper mesh" for strainers on servicing trucks and trailers, but this information is somewhat contradictory. It is stated in Par. 4-19 that the line strainers have 4- to 25-mesh screens, depending upon type of equipment involved. However, Par. 4-24 mentions that the strainer assembly for installation on the inlet end of suction hose will have 4- and 8-mesh screens for preventing the collapse of the 100-mesh intermediate screens. It appears that line strainer placement and mesh will be governed by the requirements of the individual type of pumping system.

F. Filter-Separators

1. General

The present types of filter-separators used in Air Force base fuel handling facilities have evolved from older types of water separators ("hay-tanks") and micronic filters. Correspondingly, the variety of equipment in service has been made even more diverse by the use of "conversion kits" to modify older equipment so that it will perform the filter-separator function. This diversity of equipment is reflected in the existence of a great many T.O.'s containing information on filter-separators and filters, and this may be responsible for a certain amount of confusion that exists on criteria for changing filter-separator elements. This section includes a discussion of some of the principal types of filter-separators in current service, as well as the T.O.'s governing their operation and servicing.

Filter-separators are a required installation on lines to truck fill stands, as discussed previously (AFM 86-4, Par. 40). Each operating storage tank in hydrant systems is equipped with a filter-separator. This was formerly a water separator ("hay-tank"); the conversion to filter-separator is covered by T.O. 37A9-1-506. In the older Panero systems, the fuel after leaving the water separator (or conversion-kit filter-separator) passes through a micronic filter located in the filter-meter pit; this is the last-chance filter before the fuel enters the aircraft. In the newer Pritchard systems, the final filtering function is moved to the hose cart. Some of the

early equipment of this type used micronic filters on the hose carts; these have since been converted to filter-separators. In refueling by truck or semitrailer, the fuel passes through a vehicle-mounted micronic filter or filter-separator. All of the newer units carry filter-separators, and many of the older units have been converted from micronic filter to filter-separator. It is stated in T.O. 42B-1-1, Par. 4-30 that "only those refueling vehicles equipped with filter-separators will be used for servicing jet fuel to aircraft."

2. Element Change Criteria for Fixed Filter-Separators and Filters

The T.O. and manual criteria for element replacement in fixed filter-separators are given in Table 33. Although there is some confusion on the criteria for fixed filter-separators, it appears that the current thinking is exemplified by T.O. 42B-1-1, which calls for pressure drop per manufacturer's recommendation, 18 months' service, or 5,000,000 gallons for 600-gpm units and 2,500,000 gallons for 300-gpm units.

There are two difficulties involved in applying these criteria. The first difficulty is the lack of any convenient method of determining gallonage in most fixed filter-separators. In the absence of meters in most fixed installations, this gallonage criterion is widely ignored. It appears that, if gallonage criteria are to be applied at all, methods of computing or estimating gallonage would have to be specified.

The second difficulty concerns the "manufacturer's recommendation" on maximum pressure drop. The use of such a criterion implies that valid and up-to-date figures are available. It appears that nameplate data will not always meet these requirements. The following are the nameplate recommendations for element change on the fixed filter-separators that have been noted at various Air Force bases, some of which were examined in connection with another program:

Manufacturer and Model No.	Element	Criteria for Change
Bowser 903	47B37	3.5 psi
Bowser 842B-600CL-FC	47B37	3.5 psi
Bowser 842-CL-MI (600 gpm)	47B37	6.5 psi
Bowser 842DL-300CL-FC4	47B37	6.5 psi or 1 year
Bowser 842DL-300CL	47B37	6.0 psi or 1 year
Bowser 842DR-300CL-FC4	47B37	6.0 psi or 1 year
Bowser 842DR-500CL-FC4	47B37	6.5 psi or 1 year
Bowser 842DR-600CL-FC4	47B37	6.0 psi or 1 year
Bowser 842D-CL-F4	A-1389A	15.0 psi or 1 year
Bowser-Briggs 1842D-300CL-FC4	A-1389A-30	17.0 psi *

*Curves showing 17 psi max, 2 psi min, at rated flow.

TABLE 33. ELEMENT REPLACEMENT IN FIXED FILTERS AND SEPARATORS

Reference	Type of Unit	Criteria for Element Replacement
AFM 85-16, Par. 42c	Filter-separators in hydrant systems (new or conversion jobs)	Pressure drop (mfr data) or 18 months
SACM 67-2, Par. 40f(2)(a)	Same	Pressure drop (mfr date)
T.O. 42B-1-1, Par. 4-49b	Fixed filter-separators in general	Pressure drop (mfr data), 18 months, or throughput of 5,000,000 gal*
T.O. 37A9-1-506	Filter-separators in hydrant systems (conversion jobs)	Same
T.O. 37A9-3-1-101** Par. 6-10	Water separators (old hydrant systems)	Pressure drop (10 psi or as directed)
AFM 85-16, Pars. 43b, 121b	Micronic filters in filter-meter pits	Pressure drop (mfr data) or throughput of 2,000,000 gal
T.O. 42B-1-1 Par. 4-49a	Same	Same
T.O. 37A9-3-1-101** Par. 6-10	Same	Pressure drop (10 psi or as directed)

*Throughput of 5,000,000 gal for 600-gpm units, 2,500,000 gal for 300-gpm units, and proportional amounts for units of other capacity.

**Similar information in T.O. 37A9-5-1-101.

Manufacturer and Model No.	Element	Criteria for Change
Erie dehydrators converted with Briggs BFS 26-300	A-870	Not recorded
Erie dehydrators converted with Briggs BFS 50-600	A-870	7.5 psi
Warner-Lewis FLS-245ANW	CC-5	12.0 psi
Warner-Lewis M-397P Model FC-5E3	CC-E-3	12.0 psi

It will be noted that the same element (47B37) is listed for 3.5 psi and for 6.0-6.5 psi*. Nameplate data may not always be a reliable guide to manufacturers' recommendations for two reasons: (a) Newer test data may lead to revised recommendations that are not reflected on the nameplates of existing equipment, and (b) procurement of replacement elements by competitive bidding will lead to the use of elements other than "original equipment," which will not necessarily have the same pressure-drop characteristics. A case in point is the use of the I-312 elements of Filters, Inc. to replace Bowser 47B37. The Bowser nameplate data are still used as criteria, although they are not necessarily applicable.

Returning to the data of Table 33, it will be noted that micronic filters in filter-meter pits are changed after 2,000,000 gallons throughput, in comparison with 5,000,000 gallons for filter-separators of the same capacity. The reasons for this lower gallonage and for the lack of any service life criterion are not at all clear.

3. Element Change Criteria for Mobile Filter-Separators

There do not appear to be any general criteria for element change on mobile units. Some bases will apply T.O. 37A9-1-506, but the application of this T.O. to mobile units appears to be unjustified. The only T.O. mentioning element change criteria for mobile units in general is T.O. 37A-1-101, Pars. 4-36 and 4-37, which merely states that the micronic filters on vehicles are to have the elements changed at pressure drops as directed in the T.O.'s applicable to the particular vehicle.

The current T.O. criteria for mobile-unit element change are listed in Table 34. Although these were brought up to date through February 1964, they

*Nameplate change to indicate 10 psi has been observed at one Air Force base with filter-separators using 47B37 elements.

TABLE 34. ELEMENT REPLACEMENT IN MOBILE FILTER-SEPARATORS

Vehicle	T.O. No.*	Filter-Separator	T.O. Criteria for Element Replacement
F-6 refueler (Heil, Std. Steel)	36A9-3-8-1	Warner-Lewis VFCS-458-5K3 or -5K3-2	15 psi, 18 mo, or 5,000,000 gal (2,500,000 gal per 300-gpm assembly)
MJ-1 refueler (Std. Steel)	36A9-3-13-1	Warner-Lewis VFCS-858-9K3 or -9K3-2	15 psi, 18 mo, or 5,000,000 gal
R-2 refueler (Heil)	36A12-13-7-1	Warner-Lewis VFCS-1216-18K2	15 psi or 12 mo
R-2 refueler (CDEC)	36A12-13-8-1	Briggs BFS-15-V 600 (CDEC Part 26192-1005)	14 psi** or 12 mo
F-7 refueler	36A9-3-9-1	T.O. refers to micronic filters rather than filter-separators	
Hose Carts			
MH-2 (Pryor)	37A2-2-4-1	Warner-Lewis VFCS-1259-12K2	15 psi, 18 mo, or 5,000,000 gal
MH-2 (Garsite)	37A2-2-4-11	"	"
MH-2A(CDEC)	37A2-2-4-21	Bowser 22W46	15 psi, 18 mo, or 5,000,000 gal
MH-2A(CDEC)	Nameplate*** (Kelly unit)	Briggs BFS-11/10-V-600	15 psi** or 12 mo
Serv-a-Jet (Bowser)	40W6-3-1	Bowser	6 psi (automatic), 18 mo, or 5,000,000 gal
MV-2 (Permanent Filter)	40W6-3-11	Permadry 520-42	10 psi (automatic)

*T.O. number given is that of "Operation and Service Manual." Also reviewed "Overhaul Instructions" and "Parts Breakdown" in each series.

**Maximum and minimum differential pressures vs flow rate are shown on nameplates. Curves for CDEC R-2 also appear in T.O.

***There is no T.O. covering MH-2A units carrying this filter-separator, so far as can be determined from current indexes.

do not reflect several changes initiated recently in extending the change period to 24 months. It is understood that this increase has already been accomplished for the MJ-1 and F-6 refuelers, is in process for the R-2's, and is under consideration for the hose carts. In the case of the R-2's, it is also understood that the change period for the CDEC model was increased recently to 18 months (in line with the Heil model). None of these changes showed up in the currently available T.O.'s.

It is understood that a current revision of T.O. 37A-1-101 dated 16 April 1964 is consolidating the criteria for element change in mobile filter-separators. These criteria are said to be 24 months, 5,000,000 gallons (for 600-gpm units), or a differential pressure of 15 psig. This new T.O. was not available for our review at the time of writing, but is said to apply to the MJ-1, F-6, R-2, MH-2, MH-2A, and F-6 units. The MV-2 and R-4 units are equipped with automatic shutdown at specified pressure drops, so the general criteria presumably do not apply to these units.

The statements in SACM 67-2 relative to element change on hose cart filter-separators are quite contradictory. In Par. 40g(4)(f), referring to MH-2, MV-2, and R-4* units, it is stated that differential pressures as given in the applicable T.O. will be cause for element replacement. In Par. 40g(2)(b), referring to the duties of the hydrant refueling operator, it is stated that a differential pressure of 10 psi is cause for element replacement. In Par. 40g(4)(g), referring to the MV-2 and R-4 units, it is stated that these units shut off automatically at 8 psi, and this is cause for element change. The applicable T.O.'s list 10 psi for the MV-2, 6 psi for the R-4, and 15 psi for the MH-2 and MH-2A.

Almost all of the applicable T.O.'s show pressure drop and time criteria, and most of them also show maximum gallonage. A puzzling situation exists on the MV-2 units, where the T.O. gives only the pressure drop criterion, i.e., automatic shutdown at 10 psi. The T.O. does state: "Inspect this unit in accordance with established USAF procedures based on operating hours or gallons transferred." However, since there are no "established USAF procedures" for mobile units in general, this statement has no force. One base was found to be applying the Bowser Serv-a-Jet time and gallonage criteria to the MV-2; another base was not using any time or gallonage criteria at all - i.e., they would change the elements only if the automatic shutoff operated and thus indicated excessive differential pressure. In this case the

*The designation R-4 is used for the Bowser Serv-a-Jet unit (T.O. 40W6-3-1). This appears to be commonly used terminology, although the T.O. does not carry the R-4 designation and there seems to be some confusion on the early designations of this unit and the Permanent Filter MV-2.

name of the manufacturer, "Permanent Filter," probably contributed to the impression that time or gallonage criteria are unnecessary for this unit.

4. Rejuvenation of Used Elements

Backwashing of dirty elements apparently was once an acceptable practice, but is now frowned upon. The only specific prohibition of backwashing in the T.O.'s and manuals appeared recently in T.O. 42B-1-1, Par. 4-50. Some of the older T.O.'s mention backwash lines and how to arrange the valving for such an operation. If backwashing is to be entirely prohibited, this should be spelled out clearly in both the general manuals and T.O.'s and in the T.O.'s on specific equipment.

It is also noted that, in the current T.O.'s for the Bowser Serv-a-Jet unit, mention is made of removing the elements and rapping them to dislodge dirt; this is presented as an emergency measure.

5. Minimum Allowable Differential Pressures

Another question relating to element replacement criteria is the need for minimum pressure differentials: this question is largely ignored in the manuals and T.O.'s. No mention of minimum pressure differentials has been found in SACM 67-2 or in AFM 85-16. In T.O. 37A-1-101, referring to micronic filters on vehicles, it is stated (Pars. 4-36, 4-37) that "a sudden drop in filter pressure differential is an indication of ruptured elements." Per T.O. 42B-1-1, Par. 4-50: "Whenever differential pressures are obtained any large increase of pressure with a short period of element use, or any decrease of differential pressure, indicates that the operation of the filter-separator is not normal and that contaminants may be present or the elements have failed." The T.O.'s on specific refuelers give definite differential pressures in most cases. For the F-6, it is stated that "in the event that pressure differential drops below normal (approximately 2 psi), the filter-separator involved will be disassembled and all cartridges inspected for rupture." Essentially the same statement appears in the T.O. for the MJ-1 refuelers. For the Heil R-2 refueler, a "normal" pressure differential of 2.5 psi is cited. For the CDEC R-2 refueler, a more quantitative approach is used; curves of maximum and minimum allowable pressure differentials vs flow rate are given in the T.O. and also on the filter-separator nameplate. In the case of hose carts, the T.O.'s do not even mention minimum differential pressures. Certain MH-2A units have filter-separators with nameplates showing differential pressure curves (maximum and minimum) vs flow rate. However, as mentioned previously, these are Briggs filter-separators rather than the Bowser units specified in the T.O.

6. Measurement of Differential Pressures

The heavy emphasis on differential pressure as a major criterion for element change implies that accurate and reliable measurements are available. Older fixed filter-separators had ordinary pressure gages on the inlet and outlet. Another system was the use of a three-way valve with single gage to read either inlet or outlet pressure. The use of a single gage will eliminate gage-to-gage variations but does little to improve the precision of reading, which is a particular problem in attempting to read differentials to within 1 psi under a total pressure of approximately 125 psi. Within the past three years, true differential gages have been installed on all fixed filter-separators at most if not all SAC bases. The installation consists of filter-separator inlet and outlet connections to the gage and a balance line across the gage; all three lines are provided with shutoff valves. There are at least three or four manufacturers represented in the gages observed at various SAC bases. One of these makes has given very excellent service, and another make has given extremely poor service, such that the readings are considered worthless.

There has been little or no mention of the differential pressure gages in the manual and T.O. literature. The only specific reference that was found was in T.O. 37A-1-101, Par. 4-37 (referring to micronic filters): "In some instances differential pressure gages have been found to be defective. These gages will be tested for accuracy every three months or every 300 operating hours, whichever comes first."

In view of the extremely poor performance of at least one make of differential pressure gage, it would seem in order to provide for replacement of all defective gages by those of another manufacturer.

The mobile filter-separators have various arrangements for reading differential pressure, including two separate gages, two-pointer gages, and true differential pressure gages. In addition, the MV-2 and the R-4 (Serv-a-Jet) are equipped with automatic shutdown equipment that operates when the differential pressure reaches the set point. So far as is known, no major difficulties have been experienced with the differential pressure gages or automatic shutdown equipment on any of the mobile units.

In order for differential pressures to be meaningful, it is necessary to make the measurements at full rated flow or to have available a calibration curve of differential pressure vs flow rate. Such curves are provided with only a very few types of filter-separators in Air Force service. In the other cases, where only a single figure is provided for maximum allowable pressure drop, it should be stated clearly that this refers to full rated flow; many of the T.O.'s do not make this distinction.

Although a form (AFTO 50-D) is provided for recording differential pressure measurements, it appears that maximum utilization of these data is not being obtained at most bases. It is likely that a strong quality control unit with adequate personnel could make maximum use of these data in detecting malfunctioning equipment.

7. Pretesting Elements

It has been recommended in T.O. 42B-1-1, Par. 4-48 that filter-separator elements should be pretested: "Care must be exercised in handling the elements, for any tear or puncture in any element installed will result in ineffective operation of the entire unit and in essence the entire system. Elements, therefore, should be tested before being installed." No test method is suggested. The only information in the manual and T.O. literature pertaining to this subject is in T.O. 37A-1-101, Par. 4-38, and this refers to micronic filters on servicing vehicles. A bubble test is described for checking the integrity of pleated filter elements. This is not applicable to coalescer elements, which require an actual coalescence test to determine whether they are functioning properly. Bubble tests on separator elements can be made rather readily by the manufacturer and in most cases are probably used for quality control. Coalescing tests cannot be run by the manufacturer except on a random-sampling basis, since the test is destructive from their point of view - the coalescers cannot be dried out satisfactorily for shipment. From the point of view of the Air Force base, coalescing tests on every element to be installed would be laborious but not prohibitive. The bubble and coalescing tests are used in qualification tests of filter-separators and elements, and it would not be at all out of the question to incorporate these tests as a quality control measure on purchased elements. Such tests could be run either when the elements were received or just prior to installation. In the former case, it would be necessary to provide safe storage for the fuel-soaked elements.

An alternate and possibly better quality control method would be a rigid inspection and test of each filter-separator after installing new elements. Ideally, the test would incorporate water and dirt injection, but this would require fairly complicated equipment, preferably portable. If such testing could be accomplished, it would serve to check on the tightness of element seals and gaskets, as well as the integrity of the elements themselves.

G. Aircraft Refueling, Defueling, and Sump Draining

1. General

Operations involving both fuels supply and aircraft servicing groups will naturally involve some conflicting interests and some confusion on responsibilities and duties. The present review is written primarily from the viewpoint

of the fuels supply groups, since the T.O.'s and manuals used by these groups were more accessible for review. The T.O.'s used by aircraft servicing groups are quite voluminous and naturally contain a relatively small proportion of material of interest in fuel problems. Two T.O.'s relating to ground handling, servicing, and airframe maintenance of the B-52 aircraft have been reviewed in some detail and the pertinent information summarized here. No similar documents for other aircraft have been examined. Another document reviewed was T.O. 00-25-172, Ground Servicing of Aircraft and Repositioning of Equipment, which is concerned primarily with safety precautions and is of little direct interest in fuel contamination problems.

2. Refueling Operations

In SAC practice, refueling samples are taken in accordance with SACM 67-2, Par. 18b, which requires a sample from each filter system (refuelers, filter-meter pits, and hose carts) during the first operation of that system each day. Each sample is checked visually and then taken to the base laboratory for testing for solids and water. The filter systems are rotated so that each is checked at least weekly, but this requirement is waived in the case of alert aircraft parked over a filter-meter pit when there is no fuel servicing to or from that particular aircraft. In case entrained water is visible in any refueling sample, the unit will be resampled; if water continues to appear, the unit will be shut down for inspection by maintenance personnel and element change if needed. Each sample is also checked visually for solids, and more than four or five fibrous or metallic particles are cause for shutdown without further test. In either case, tests are to be made of the filter or filter-separator effluent before placing the unit back in service. Thus, refueling is never delayed except when the fuel is visibly contaminated. The solids determination in the laboratory serves merely as a more accurate check on filter condition. Solids under 8 mg/gal (approximately 2 mg/liter) are considered satisfactory. If over this limit, they are ashed to determine the noncombustible solids; here again, 8 mg/gal is considered satisfactory. So far as can be determined, the Karl Fischer water determinations do not play any role in determining when a filter system should be isolated for corrective action.

There is no mention in any of the T.O.'s or manuals of exactly when during the refueling operation the sample should be drawn, and it is only in recent T.O.'s that there is any emphasis on the necessity or even the desirability of drawing the sample while the system is operating at full flow rate. This is mentioned in T.O. 42B-1-1, Par. 4-14: "A sample representing fuel serviced to aircraft will be taken at least once a day, from each filter system. The sample will be taken from the nozzle at the operating flow rate, where possible. This sample will be observed visually for appearance, water, and sediment. Any discrepancy will be cause to stop use of the unit and inspect

filter-separators." Similar information on sampling is given in T.O. 42B1-1-13.

It should be noted in passing that neither SACM 67-2, T.O. 42B-1-1*, nor 42B1-1-13 requires any samples whatever from the effluent of fixed filter-separators on truck fill stands nor on the operating storage tanks of hydrant systems. These are not subject to any quality control of this sort. This lack would seem to be particularly dangerous in the case of the Panero system, where passage of any water by the filter-separator would result in almost immediate contamination of the stream entering the aircraft. This situation does not occur either with Pritchard hydrant systems or with refueling vehicles, as there is another "last-chance" filter-separator in each of these cases.

3. Defueling Operations

The question of quality control on defuel appears to have been largely ignored. Apparently there are no specific instructions on sampling or examination and testing of defuel samples. The approach is somewhat negative; i.e., the fuel is to be drained into regular storage or field servicing truck "unless such fuel is indicated to be unfit for further use in aircraft" (T.O. 42B1-1-1, Par. 5-31). Since fuel removed from contaminated aircraft is a recognized source of chlorides and microbial contamination, it would appear that some positive approach to checking the quality of the defuel would be a definite aid in maintaining base fuel system cleanliness. At one base (Bergstrom) a local procedure had been issued calling for visual check on Panero defuel.

As mentioned previously, there is some controversy over whether or not the defuel passes through the filter-separator on the various hose carts. According to the T.O.'s, it does so in all models. When defueling by vehicle, the defuel obviously can pass through the filter-separator when pumping out of the vehicle tank back to base storage; in most cases, the filter-separator can also be used while unloading from the aircraft to the vehicle tank. Only in the case of defueling direct to a Panero hydrant system is there no chance for any fuel filtration.

4. Aircraft Sump Draining

The only detailed instructions on sump draining in the T.O.'s on fuel handling are given in T.O. 42B1-1-9, Par. 4-1 through 4-10; these are

*The current version of 42B-1-1 mentions the desirability of such sampling, but it does not seem to be spelled out as a requirement.

quoted here in part: "... Aircraft will be refueled as soon as possible after landing ... keeping out snow, water, and ice ... Fuel tanks, filter cases, and pumps will be drained on preflight inspection. Enough fuel will be drawn from each drainage point to insure that the fuel tank, filter, or pump has no contamination or water in it. ... A minimum time period of preferably one hour, but at least 30 minutes, shall elapse between filling of the fuel tanks and drainage of the fuel tanks, filter cases, and pumps, unless flight schedules would be hampered by this time interval. A minimum time of one hour shall elapse after each removal of aircraft from a heated shelter before drainage procedures are begun. ... Open the drain cock slowly (to promote complete water drainage) from each drain point into a clean glass or plastic container to permit a careful examination for the presence of water and other contaminants. Continue draining slowly until fuel is free of water. If other contaminants are present, the petroleum officer will be advised. ... It is suggested that one or two drops of a water soluble food coloring . . first be placed in the container to aid in distinguishing the water from the fuel. ..." An earlier version of this T.O. stated that fuel tanks, filter cases, and pumps should also be drained after each flight.

Details on the frequency of sump draining and the location of the drain points are given in the T.O.'s covering ground handling, servicing, and airframe maintenance of individual types of aircraft. Two such T.O.'s were reviewed - T.O. 1B-52B-2-2, covering B-52B through B-52F aircraft, and T.O. 1B-52G-2-2, covering the B-52G and B-52H. These aircraft have about 28 drain points. Both T.O.'s require sump draining within eight hours of takeoff for aircraft that are on normal flight status. For alert aircraft, the T.O.'s require sump draining once in each 72-hour period and following each refueling (allowing maximum use of settling time). Comments of aircraft servicing personnel had indicated that daily sump draining was required for B-52's on alert status, but no such requirement appears to exist in these T.O.'s.

The basic procedure followed in maintenance sump draining of B-52's is essentially that of 42B1-1-9, using a half-gallon bottle. Similar procedures are used on KC-135's. In the case of B-58's, the tanks are relatively flat and shallow and have no actual "sumps" for the accumulation of water. Routine draining of fuel tanks is performed sometime after refueling and again before flight in case the plane has remained overnight. The T.O.'s applicable to KC-135 and B-58 aircraft were not obtained for review.

Superimposed on these regular sump drains performed by the aircraft servicing crews, there is the sampling for laboratory analysis. SACM 67-2 states that a "daily composite sample" is to be taken from the sump drains of at least one aircraft per assigned squadron; if possible, this is to be taken from an aircraft serviced the previous day and allowed to stand overnight. The

sample is to be checked visually and forwarded to the base fuel laboratory. Exactly how, when, and by whom the sample is to be taken is not stated, and much confusion and some friction seem to have been generated. It is doubtful whether a "composite" sample is ever obtained, in view of the large number of drain points. In most cases, it appears that the laboratory personnel do not have any knowledge of the maintenance drain schedule, and in some cases the laboratory personnel are not allowed access to the aircraft for their own sampling. As discussed in more detail in the following section, this makes it very difficult to interpret the results of visual examination and laboratory analysis of the samples.

H. Fuel Sampling and Analysis

1. General

In considering the overall program of base fuel quality control, it should first be noted that at present the SAC bases differ from most other Air Force bases in that they have set up laboratories for Millipore and Karl Fischer analysis, and (more recently) for anti-icing additive content of fuels. Thus, when the frequency of analyses is discussed here, it is understood that this is applicable only to SAC bases or other bases with fuel laboratory facilities.

As a general guide to the sampling points that might be considered desirable, the following is quoted from MAMA letter MAOQ 64-1*: "... installation of sampling connections at the following locations will assist in permitting evaluation of the functioning of the system and indicate the location of problem areas:

"1. On suction lines from aboveground storage tanks, and on discharge lines from underground tanks.

"2. On upstream side of each filtration unit (filter/separator, filter, water/separator).

"3. On downstream side of each filtration unit.

"4. At all dispensing points of the system including hose carts for hydrant systems."

The frequency of sampling for analysis is given in this same MAMA letter, and also in SACM 67-2, as shown in the following comparison:

*These are also included in the current version of T.O. 42B-1-1.

	Frequency of Sampling and Analysis	
	SAC	MAMA
Truck fill stands	No requirement	Daily, from each used
Hydrant pumphouse filter-separator	No requirement	Daily, from each used
Refueling vehicle, hose cart, and filter meter pit	Daily, from each used; all to be sampled at least weekly	Weekly, from each used
Bulk storage tank	Yearly	Daily
Tank car, tank truck, barge, or pipeline receipt	Daily (one from each type of receipt)	Each shipment (visual only)

Thus, it is seen that the sampling requirements recommended by MAMA are somewhat more extensive than those required by SAC. The amount of sampling recommended by MAMA is certainly desirable.

2. Incoming Fuel Samples

Quality control of fuel receipts is primarily a function of source inspection and Air Force Quality Control. In the case of tank car and truck receipts, quality control at the Air Force base is confined to visual examination of top-level samples (and daily laboratory checks on bottom-level samples in the case of SAC bases). There seems to be some disagreement on whether or not the tank car or truck bottoms need checking, and it is probable that in many cases even the top-level check is omitted.

3. Bulk Storage Samples

There is no information in the T.O.'s or manuals to indicate any requirement for frequent bulk storage sampling*. T.O. 42B-1-1, Sec. V specified that dormant storage stocks are to be sampled any time quality is suspected, or at least once a year. SACM 67-2 requires that samples are to be drawn from bulk storage for analysis at the intervals specified in 42B-1-1 (12 months for jet fuels), whether or not the storage is "dormant." These are nominally all-levels samples and are submitted to Air Force area laboratories for analysis.

*But MAMA letter MAOQ 64-1 recommends daily sampling.

There does not appear to be any organized sampling or analysis of bulk stocks at the base level, except as instituted by individual bases. At Carswell AFB, for example, bulk tanks are sampled weekly for Millipore and Karl Fischer analysis. These samples are drawn from a few feet below the top level. Water bottoms are sampled monthly for sulfide test; this is in accordance with T.O. 42B-1-1, Par. 4-11.

4. Operating Storage Samples

There does not appear to be any requirement listed in T.O.'s or manuals for sampling or analysis of the contents of operating storage tanks.

Likewise, there is no requirement for sampling or analysis of effluent from fixed filter-separators. This is regarded as a serious lack, since the fixed filter-separator is the major line of defense against the entry of fuel contaminants into aircraft; in certain cases (e.g., a Panero system when settling time in bulk and operating tanks is inadequate), the fixed filter-separators may be the only place for removal of water.

5. Refueling Samples

The exact point of sampling, time of sampling, and details of sampling method are absent from the T.O.'s and manuals. The situation is changing rather rapidly, in that more and more bases are being equipped with sampling cocks on single-point nozzles, and some bases are being provided with continuous-sampling devices. It is always considered preferable to draw the sample at the "last chance," i.e., at the refueling nozzle. When such connections are not available, the sample may be drawn from sampling cocks at the outlet of the hose-cart filter-separator or at the outlet of the micronic filter in the case of Panero refueling. Full-flow samples are always preferable, but it seems that this is not spelled out as clearly as it should be. In the case of over-the-wing refueling, it may be necessary to take samples from the nozzle delivery tube itself, which makes it difficult to obtain full-flow samples.

As mentioned in the preceding section, daily samples are required from each "filter system" the first time it is used in a given day. This gives a rather large number of samples; for example, Carswell at the time of the survey had four MV-2 hose carts, nine Panero filter-meter pits, and fifteen refuelers in JP-4 service. Since most of these were being used at least once in a normal day, these 28 refueling samples, plus additional samples from bulk storage and receiving and from aircraft, were burdensome. Neither of the SAC bases surveyed had yet been able to meet this requirement, but both bases were attempting to step up their schedule of analyses by shift operation and/or additional personnel.

Apparently some bases are drawing samples for visual inspection at every refueling operation. None of the fuel handling T.O.'s require such frequency of sampling, but it appears to be an excellent idea and probably should be mandatory. Visual examination of fuel samples is discussed in more detail in a later section.

6. Aircraft Sump Drain Samples

The laboratory sampling requirement of one sample per day from each type of aircraft is superimposed on the regular sump drains performed by the aircraft servicing crews. The samples for the laboratory are supposed to be "composite" sump samples, but it appears that this is largely ignored. The exact method of drawing these samples and the interpretation of the test results are very indefinite in the applicable documents. The interpretation at Bergstrom AFB was that a gallon sample should be drawn from a given sump (B-52D and KC-135 aircraft) and brought back to the laboratory. Then the top quart of this was poured off for solids and water content determinations. The bottom portion of the sample was not used, except that the amount of water was recorded. These samplings were performed by laboratory personnel, and might precede or follow after a regular maintenance sump drain. At Carswell AFB, the samples for the laboratory were drawn by aircraft servicing personnel. Samples from B-52F aircraft were said to be drawn immediately after the regular half-gallon sump drain; samples from B-58 aircraft were said to be taken as "first drainings," i.e., without any flush of the line. The frequency of sampling at both bases was far below the specified one per day for each type of aircraft.

Interpretation of the laboratory results on sump drain samples is nearly impossible because of the lack of knowledge of the history of the samples and the aircraft. Also, it is fairly obvious that tank bottom samples are going to have appreciable quantities of solid material and in most cases water. If analysis shows excessive quantities of either, the usual procedure is to go back and resample until satisfactory material is finally obtained. It appears that visual examination in this case would yield about as much information as the laboratory analyses.

7. Visual Inspection of Samples

The criteria for visual inspection of fuels are scattered through the applicable documents. T.O. 42B-1-1 contains valuable information on sampling method, definition of terms, and color photographs showing different types of contamination.* The use of water-soluble dye in identifying water in sump-drain

*In the current issue of T.O. 42B-1-1, the color photographs are reproduced so poorly as to be of little or no value.

samples is covered in T O. 42B1-1-9, Par. 4-6c. Visual examination of samples taken during refueling is covered in SACM 67-2, Par. 18b; here there is no discussion of the methods of sampling and examination, but it is stated that the presence of visible entrained water or more than four or five fibrous or metallic particles is cause for shutdown and inspection of the filtering system.

Considerably more reliance could be placed on visual inspection of fuels at all points in the system, especially at the refueling point. It is believed that a more accurate definition of the procedure is necessary to obtain maximum benefit from visual examination. This definition should include the exact shape of the sample container (preferably square, with plain bottom), the lighting conditions, and a description of acceptable levels of contamination in terms of cloud, dust or rust particles, fibers, metallic particles, and other contaminants. It should not be out of the question to provide each hose cart and refueler with a simple device for viewing samples under constant lighting and background conditions. Further, a sample bottle of prefiltered fuel should be provided for comparison.

The MV-2 and Serv-a-Jet hose carts are each provided with a "look box" in the effluent line. It was not determined whether this is considered to be of any value in detecting contaminated fuel. Offhand, it would appear that such a device could be of considerable value if proper illumination were provided.

8. Millipore Solids Determination

The test method for total solids is quite well standardized and does not require comment here. However, it should be mentioned that the limit of 8 mg/gal of noncombustible solids, as specified by SACM 67-2 for refueling samples, is certainly not very restrictive. First, it appears desirable to base the criterion on total solids rather than noncombustible solids, since the combustible (organic) solids may be equally as bad as the noncombustible (inorganic) solids in the aircraft fuel system. It should be kept in mind that filter-separator qualification tests require effluents with total solids contents of about 2.6 mg/gal. It is true that qualification tests are run with arbitrary standard contaminants and with fuel of controlled quality. However, it is still believed that some effort should be made toward lowering the present limit of 8 mg/gal on refueling nozzle samples.

9. Karl Fischer Water Determination

The mechanics of the procedure using KF-3 apparatus are spelled out quite well in T.O. 42B1-1-13. However, a serious question arises on the significance of the saturation value as determined by this method. The saturation

sample is held in a bottle with distilled water in a cold tap water bath for 16 hours, after which the water content of the supernatant fuel is determined and taken as the "saturation limit." Samples from refueling operations or elsewhere in the system are held in this same bath for at least one hour, then thoroughly shaken to get a representative sample for titration. The interpretation of results as stated in the T.O. is: "The water content of the saturated fuel sample ... is the maximum amount of water that can be dissolved at tap water temperature. When the water content of the fuel sample being tested ... exceeds the water content of the saturated fuel by more than 5 parts per million, by volume, the fuel is not satisfactory for use. ... If the water content of a fuel sample is less than that of a saturated sample, this means that the fuel is not fully saturated with water."

It is believed that there are several fallacies in the procedure and interpretation given in this T.O. First, the saturation value determined by this method is essentially the solubility of water in the fuel itself, i.e., in fuel without anti-icing additive. During the 16-hour equilibration period, the additive in the fuel will be extracted almost quantitatively into the water phase, giving a concentration of not more than about 0.3% additive in the water. The equilibrium water content of fuel in contact with such a water solution will be essentially the same as if in contact with pure water. However, this does <u>not</u> represent the maximum water content (solubility limit) of the original fuel containing 0.1% additive. Such a true solubility limit is much more difficult to determine, and there are indications that the true solubility limit may be somewhat lower than the value determined by the usual method.

Second, it appears that the method of handling the fuel sample can lead to serious anomalies. Fuel samples are held one hour in a cold-water bath, after which they are "shaken thoroughly to obtain a representative sample." If the sample, as taken, contains entrained water, the difficulty in obtaining a representative sample for titration is very considerable. When gross amounts of water are present, there is no particular problem; enough of the water can be redispersed to register high water contents, and such large amounts of water are usually detectable by visual examination anyway. The problem comes when water content is marginal. If the sample bottles are left to settle for very long, as may well happen in weekend refueling operations, small amounts of entrained water can be "lost" by settling out on the bottom and sides of the bottle and may be invisible and almost impossible to redisperse. The important points here are that (a) samples should be analyzed as soon as possible after they are drawn and (b) they should be agitated very thoroughly and vigorously before drawing the sample for titration. In this latter connection, it would be desirable to insist that sample bottles be filled not more than about 70%, to facilitate the redispersal of water.

Third, there seems to be neither merit nor need for placing the fuel samples in a cold-water bath prior to drawing the samples for titration. Presumably the original assumption was that the tap water would always run about the same temperature as that of the fuel system, but this is certainly not true of the entire system. If fuel sampled at 80°F is then cooled to 60°F in a tap water bath, the fuel will approach saturation or may even drop out water if it was near saturation to begin with. Thus, the fuel could be rated as unsatisfactory even though it were below saturation when sampled. The reverse situation would be more apt to occur in the winter, i.e., a fuel containing entrained water when sampled could be warmed up in the tap water bath so that the excess water would be dissolved and the sample would be rated as satisfactory.

It is believed that these three shortcomings in the existing procedures are largely responsible for the general lack of confidence in water determinations. If these determinations are to be of real value, it will be necessary to correct these shortcomings. The effect of anti-icing additive on water solubility should be investigated, using whatever data are already available and obtaining additional data as necessary in order to develop suitable correction factors to the saturation values as presently determined. In the laboratory instructions, heavy emphasis should be placed on prompt analysis and vigorous shaking of sample bottles to redisperse all water possible. Sample bottles should not be filled more than about 70%. Finally, the fuel samples should not be held in the cold water bath, but should be analyzed as soon as possible. Having available a set of generalized curves for water solubility in JP-4 fuels vs temperature, the daily saturation curve can be sketched in from the single data point (saturation sample). This curve is then used to read off the saturation value corresponding to the sampling temperature of a specific sample, and the sample is rated on the basis of so many parts per million above or below this saturation value. This rating system has been used in connection with a survey of Air Force bases under another contract and has proven to be workable, relatively simple, and reliable.

10. Determination of Anti-Icing Additive Content

The standard methods of analysis for the content of anti-icing additive in fuel samples are based on oxidation of the additive with excess dichromate and determination of the excess dichromate either by titration with thiosulfate or by comparison with color standards. The titration method is covered by Federal Test Method Standard 791a, Method 5327.1. The color comparison method is given in T.O. 42B-1-1 and is given in somewhat more detail in a procedure dated 18 September 1962, "Visual Colorimetric Determination of Fuel System Icing Inhibitor in Hydrocarbon Fuels," issued by MAMA-MAOQL. This method has subsequently become Method 5330 of FTMS-791a.

In either of these methods, the additive content is determined by comparison with a standard additive blend or blends, and this implies that "standard" additive is available. Since the glycerin content of the anti-icing additive has been changed twice within the last two years, there is naturally some confusion as to what is the "standard" additive. The present glycerin content (0.4%) is so low that the use of straight methoxyethanol as the standard additive would not introduce any significant error. It appears that a statement approving the use of straight commercial-grade methoxyethanol as the standard should be inserted in the test procedures.

Another method requiring mention is the freezing-point method developed by California Oil Company*. This determination is based on extracting the additive with water and determining the freezing point of the aqueous extract. Accurate freezing points are required; a freezing-point change of 1°F corresponds to about 0.04% additive. The method is quite simple and could be taught readily to untrained personnel; in this respect it is probably superior to the chemical methods. There is little if any time saved by using the freezing-point method. Comparative tests using the freezing-point and titration methods have shown that the two methods give excellent agreement (see Section V-D-1).

11. Sampling Techniques

In the current manuals and T.O.'s the methods of drawing samples are not specified in relation to the various sampling locations. Each Air Force base is quite free to apply their own methods and interpretations. Line sampling (including nozzle sampling) is the most straightforward since, once the sampling cock is installed, all that is required is a suitable small delivery tube or a funnel and the sample bottle. Problems involved in aircraft sump drain sampling have already been discussed in some detail. When samples are required from storage tanks or incoming shipments by tank car or tank truck, some type of thief sampler is required. Considerable use is made of the Bacon type thief sampler, but often difficulties are encountered with leakage of the fuel into the sampler when lowered to any considerable depth in fuel. The necessity of bottom-level, low-level, or all-levels sampling seems to be the subject of some argument, and it appears that little or no sampling of this type is actually performed. In the case of top-level sampling, the sampling device is less critical, and almost any type will suffice so long as it is clean.

Experience with a novel type of vacuum-pump sampler was described in Section III-C. With this sampler, fuel is drawn directly from the desired level

*Loomer, D. M. and Graham, A. L., Oil Gas J, 14 Jan 1963, pp. 82-84.

through polyethylene tubing directly into the sample bottle. The device is simple, relatively foolproof, and easy to clean.

One fact that is not mentioned in the T.O. and manual literature is the dirty condition of sample bottles as purchased. Cleaning of either new or used bottles is particularly important in the case of refueling samples, where personnel are instructed to look for "four or five metallic or fibrous particles." It appears that more rigid instructions should be given for cleaning sample bottles before use. This is not a matter of trying to provide true particle-free bottles for general use; it would probably be sufficient to specify that bottles are to washed with detergent and hot water, then rinsed (finishing with filtered distilled water), dried, and kept capped until ready for use. Alternatively, the bottles could be rinsed with solvents until no visible particles remained.

It is usually considered a desirable practice to rinse the sample bottle at least twice in the fuel stream or fuel from the tank being sampled. It is believed that this should be emphasized in the applicable T.O.'s, in view of the particular importance of prerinsing the bottle when taking samples for Karl Fischer water determinations.

It would be desirable to standardize on one particular shape of bottle for all sampling. Square one-quart bottles are to be preferred from the standpoint of ease of visual examination. If possible, the bottoms should be plain, i.e., not embossed or otherwise modified to obstruct vision. Screw caps with aluminum foil liners should be adopted as standard.

VII. RECOMMENDED FUEL HANDLING PROCEDURES

A. General

As a result of the review of Air Force documents on fuel handling (Section VI) and the survey and sampling program (Section III), criteria and recommended practices have been drawn up for fuel handling, sampling, and analysis in relation to jet fuel quality control. These are presented in Appendix B in Technical Order (T.O.) format. These criteria and recommended practices are intended to be applicable to all jet fuel handling operations at Air Force bases.

It is recognized that many Air Force bases do not have laboratory facilities for carrying out the analyses called out in this T.O. In such cases, major reliance must be placedon visual examination of samples, with questionable samples to be submitted to the designated Area Laboratory.

Much of the T.O. in Appendix B is a restatement of existing criteria and recommended practices as defined in current T.O.'s and manuals. However, the T.O. in Appendix B does provide a unified approach to jet fuel quality control at the Air Force base level that is not found in existing documents.

Some of the criteria and recommended practices in Appendix B are new or represent modifications of existing criteria. Some of these changes and the reasons for these changes are discussed in the following paragraphs.

B. Fuel Receipts

Receipts by tank car or tank truck represent a particular problem in quality control at the base level, since unloading schedules often will not permit detailed checking of all loads. It is recommended (Par. 2-4) that each compartment of each tank car or tank truck should be sampled by top dipping to check for the presence of any severe contamination by water or solids. In addition, at least one sample per tank car or tank truck will be verified as to grade by checking color, odor, and gravity. The presence of large quantities of free water will be checked by gaging or by taking drain samples (Par. 2-7 and 2-8).

In the case of receipt by barge, tanker, or pipeline, the individual shipments are large enough that effective checking is less of a problem. The recommended practices for such checks follow existing directives.

The settling time required in bulk tanks after fuel receipt or series of receipts is a matter of some disagreement in existing directives. The recommended settling time given in Appendix B (Par. 2-26) is one hour prior to gaging and four hours prior to issue, with a visual check on a low-level sample prior to issue. Although similar requirements appear in some existing directives, they may be largely ignored at bases with limited bulk storage capacity.

C. Bulk Storage

A recommendation is given (Par. 3-6) for the installation of more effective types of floating-roof seals whenever feasible during major maintenance or repair of older installations. More specific recommendations along this line would have been desirable, but time did not permit a comparison of the types of seals that are available.

The mandatory installation of closed-pipe roof drains whenever a tank is open for entry and inspection (Par. 3-8) does not appear in most existing directives, although it is generally recognized that the other types of roof drains are not satisfactory for jet fuel storage tanks.

A mandatory schedule of 1-year inspection and 3-year entry and inspection is given (Par. 3-12). Further, a criterion of one-half inch of sludge is cited as cause for mandatory tank cleaning. This criterion may be open to some question as to just how the average depth of sludge may be determined and whether the one-half-inch figure is realistic. However, in the absence of any detailed data on sludge accumulation in JP-4 bulk storage tanks, it appears desirable to set a definite criterion for cleaning.

It is considered that the installation of true low-point sump drains in bulk storage tanks should be mandatory whenever a tank is opened for entry and inspection, and such a statement is included (Par. 3-15).

It is recommended that the suction lines in bulk storage tanks should be placed with at least 12 inches of clearance above the tank bottom. Most existing tanks have suction lines placed much lower than this, and the higher position may not be feasible in some cases. However, it is considered most desirable that the suction point should be raised, either by fixed installation or by the use of a floating suction.

It is recommended that filter-separators should be installed in the transfer line from bulk storage to operating storage (Par. 3-24). Although such installations are not common at present, it is believed that their use would contribute to the eventual maintenance of operating storage systems as "clean" storage.

The sampling of bulk storage tanks is not covered adequately by most existing directives, since only yearly sampling is required in the case of dormant storage, and no sampling in the case of active storage. SACM 67-2 requires the submittal of yearly samples for both dormant and active storage. It is recommended (Par. 3-26) that one sample per month should be analyzed by the base laboratory as a running check on the contamination level and the content of anti-icing additive. It is also recommended that line samples should be taken for visual examination during every transfer of fuel from bulk storage to operating storage or refueling vehicles.

D. Operating Storage and Hydrant Systems

Installation of new tanks with a positive pitch, and installation of additional gaging hatches in old tanks, are recommended (Par. 4-4). It is further recommended (Par. 4-6) that the closed (slotted) gaging pipes used in most existing installations should be removed to facilitate water pumpout and to aid in obtaining representative fuel samples from the tanks. The schedule given for inspection and cleaning is the same as for bulk storage tanks.

A mandatory three-hour settling period in operating storage tanks is recommended (Par. 4-13). This will be difficult to maintain in many existing installations.

Visual checks are specified on the contents of defuel tanks prior to reservicing to aircraft or transferring to another tank (Par. 4-18). Visual checks are also specified on the contents of operating storage tanks, at least weekly (Par. 4-26).

Line samples are specified to be taken before and after each fixed filter-separator, for visual examination, during each refueling operation or other issue (Par. 4-25).

E. Refueling Vehicles

Mention is made (Par. 5-8) of the problem with tank drain valves that do not give a positive seal on closing. This appears to be a problem principally with the R-2, and fuel handling personnel are often reluctant to drain the water from these tanks because of the danger of fuel spills. It is not known whether this problem is encountered with other vehicles. However, it appears that, in such cases, some form of emergency shutoff valve should be provided.

The use of interior coating on steel refueler tanks should be mandatory (Par. 5-14); this does not appear to be the case in existing directives.

F. Micronic Filters and Filter-Separators

The element change criteria for fixed filter-separators that are given in Appendix B (Par. 6-6) are essentially those of the current T.O. 42B-1-1. However, low or erratic differential pressures have been added as criteria for change. This is also the case for micronic filters (Par. 6-7). Some discussion is given of the means available for determining total throughputs in various situations (Par. 6-8); this question has been largely ignored in existing directives and manuals.

The element change criteria that are given for mobile filter-separators (Par. 6-13) are in line with those given in a forthcoming revision of T.O. 37A-1-101, based on our understanding of these criteria. Low or erratic differential pressures have been added as criteria for change.

It is indicated (Par 6-22 and 6-24) that all differential pressure readings should be taken at full flow; otherwise, the flow rate must be indicated and the differential pressure converted to full-flow basis. It is recognized that this will introduce considerable difficulty, in that flow rates in refueling operations are variable, particularly in the smaller issues. However, it is felt that the principle that all readings must be on a full-flow basis is sound and should be emphasized.

Primary responsibility for keeping differential pressure records and establishing differential pressure criteria is given to the base fuel quality control unit (Par. 6-23 through 6-26), as well as the responsibility for determining the need for interior inspection of filter-separators and/or element replacement.

G. Aircraft Fueling and Defueling

Sampling for visual examination during every refueling operation is specified in Par. 7-5. The schedule of sampling for laboratory analysis is essentially that presently specified by SACM 67-2. Water contents more than 5 mg/liter over saturation are cited as cause for removal of the filter system from service (Par. 7-7). In existing directives, this criterion on water content is not cited as cause for isolation of the system. It appears that the use of more realistic saturation values will permit the use of water content as a valid criterion for such isolation.

Filtration of defuel before return to operating storage is specified (Par. 7-9) for all operations except Panero hydrant defueling, where filtration

is impossible. Sampling of defuel for visual examination is specified in all cases (Par. 7-10 and 7-11).

H. Aircraft Tank Draining

The principal features of this section of Appendix B (Section VIII) are the definition of responsibilities of the fuel quality control unit and of the aircraft maintenance crews, and the definition of procedures for obtaining samples. Primary emphasis is placed on visual examination, since analysis for water and solids contents of bottom drain samples is not particularly meaningful.

If close coordination can be achieved between the fuel quality control unit and the aircraft maintenance crews, it should be possible for the quality control personnel to witness the majority of the tank draining operations. Aircraft scheduling problems will clearly interfere in some cases. The important point is that the fuel quality control unit must obtain a good qualitative picture of the amounts of free water and gross solids that are found in initial draining of the aircraft tanks after refueling. This is not the case in many existing situations, in which the fuel quality control unit has no knowledge of when the maintenance drains were performed.

Aircraft tank drain checks are specified whenever the ambient temperature is above 0°F (Par. 8-8). Since the existing aircraft T.O.'s specify no drain checks when the ambient temperature is below 32°F, the present situation probably will not be changed until the aircraft T.O.'s are modified to require tank draining down to 0°F.

No laboratory analysis is specified on initial-drain samples, unless contamination is clearly indicated. One "clean-fuel" sample (following the initial drain) is specified to be taken daily from each operating squadron, in line with existing SAC procedures. However, only the anti-icing additive content is to be determined on these samples (Par. 8-15), as the water and solids contents are not regarded as significant.

The question of the control of fuel cleanliness within the aircraft is outside the scope of the present effort. However, it appears that such control could not be exercised merely on the basis of tank drain samples.

I. Fuel Sampling and Analysis

The required frequency of sampling at all points in the system for visual examination and for laboratory analysis is summarized in Table 9-1 of Appendix B. Most of these requirements differing from existing practices

have already been discussed. It will be noted that a much higher frequency of sampling for visual examination is specified in Table 9-1 than is covered by present directives.

One innovation (Par. 9-11 through 9-15) is the recording of sample temperature at the time it is taken in all cases where determination of water content is required.

Detailed directions on sample containers and sample handling are given in Par. 9-16 through 9-28.

Considerable attention is given to the methods and criteria for visual examination of fuels (Par. 9-29 through 9-36). The use of a simple viewing box is recommended for use in on-site examination of refueling samples. Unfortunately, no quantitative standards can be assigned for the guidance of inexperienced personnel. It is believed that continued use of viewing boxes under optimum conditions of illumination will enable the development of sufficient experience within the base fuel supply unit that clean fuel can readily be distinguished from contaminated fuel.

In the Millipore solids determination, it is recommended (Par. 9-43) that the noncombustible solids should not be run except as an aid to identification and that it should not be used as a criterion for the withdrawal of filter systems from service. Solids of any type, whether organic or inorganic in nature, can contribute to aircraft operational problems, and it appears unrealistic to base any criteria strictly on inorganic, noncombustible solids.

Certain improvements in the Karl Fischer water determination method are recommended (Par. 9-52), based on considerable experience. It is also recommended that Karl Fischer results be expressed in mg/liter to avoid ambiguity; existing procedures and calculation methods actually give the results in mg/liter.

A major change is specified in the method of determining saturation values by the Karl Fischer method (Par. 9-57 through 9-63). The reasons for this change have already been discussed in some detail in Section VI-H-9 and will not be repeated here. The recommended method involves saturation of the fuel sample over a limited amount of water, approximately 0.5% of the fuel volume, which is sufficient to give an adequate interface for equilibration with the fuel. The limited amount of water gives a saturation value that is more nearly representative of field conditions, since it does not extract all of the anti-icing additive from the fuel. Typical curves of solubility vs temperature are plotted on semilogarithmic paper; an example is given in Figure 9-1

of Appendix B. The saturation curve of the base fuel saturation sample is established from a single determination; this curve is used to rate subsequent fuel samples on the basis of mg/liter above or below saturation, based on the sampling temperature. Daily saturation samples are required if the bulk storage tanks are rotated daily; if one tank is used as the sole source of fuel issues for several days, the daily requirement for saturation samples is waived.

All results of laboratory analyses are normally recorded chronologically on summary forms provided for that purpose. In addition, it is specified (Par. 9-70) that running logs will be kept on each filter system or other sampling point, either in the form of tables or graphs, in order to provide a continuous check on equipment performance and system cleanliness. This log will include the results of all laboratory analyses and, in the case of filter-separators, the differential pressure readings.

VIII. REVIEW OF REPORT AND OPEN LITERATURE

A. Sources and Scope

The literature that is of interest in fuel handling and contamination problems is scattered widely, since it includes information on ground facilities and equipment, fuel properties, aircraft tanks and accessories, chemical additives, coatings, corrosion, and microbiology. The bibliography of pertinent material that is presented in the following section is intended to provide a guide to these diverse fields. Although the literature searches were not exhaustive, the bibliography is essentially complete on specific fuel contamination problems, near-complete on filtration and water coalescence, and complete since 1961 on microbial action on hydrocarbons. This does not imply that all literature of possible interest has been included in the bibliography; rather, the bibliography is selective. For example, extensive literature references on theoretical aspects of water coalescence and emulsion breaking and on electrical methods of emulsion breaking were not included. Also, it was not found feasible to include the rather large volume of Soviet literature, some of which is of considerable interest in the present context.

Surveillance has been maintained over U.S. military-agency and contractor reports for about three years, and in addition a bibliographic search was made through ASTIA (now DDC).

The bibliography is subdivided by subject matter under the same classifications used in the following discussion. Although this introduces considerable arbitrariness and overlapping, it is believed that such classification will prove useful for future reference.

B. Fuel Contamination Problems in General

Much of the material in this section is taken from a Department of Defense symposium on jet fuel contamination, held in September 1961 (2, 4, 8, 9, 17, 19, 20, 22). The minutes of this meeting represent a rather complete rundown of the situation as it existed at that time. Of the earlier general papers on this subject, particular mention should be made of three papers presented in 1957-1959 by Shell (5, 10, 11). Reference (11) discusses requirements for adequate airport storage and handling facilities, including tanks with adequate settling time and floating suction lines, as well as filter-separators in receiving and dispensing lines. Mention should also be made of a paper by W. J. Digman of Douglas (6), which discusses general aspects of fuel contamination, mainly in relation to aircraft tank corrosion.

Reference (7) provides a general review of fuel contamination problems, fuel contaminant sources, fuel contamination effects and corrosion of aircraft fuel systems.

A summary of CRC activities in jet fuel contamination problems has been presented recently (16). The minutes of a conference held by the Prevention of Deterioration Center in April 1962, on jet fuel microbiology and corrosion, are given in reference (15). The discussions in this meeting covered a wide range of subjects, and a whole broadside of research objectives and suggested lines of attack are presented.

Reference (3) shows that serious aircraft troubles have been traced to contaminants in fuels and that improper operation and maintenance of fuel handling equipment has been found to be the causative factor in each case of serious fuel contamination thus far investigated.

A summary of Air Force programs in "fuel microbiology" has been given recently in a memorandum by London (13), dealing to some extent with problems and programs not strictly microbiological in nature.

C. Microbial Contamination and Corrosion

This section deals with various aspects of microbial contamination of fuels, including some material on related subjects in microbiology.

A comprehensive review of the literature on microbial attack on hydrocarbons is given in a 1961 German article (44), which has been made available in an OTS English translation. This review, with 271 references, covers all aspects of the subject but without particular reference to fuels; the approach is fundamental rather than practical. Another bibliography on this subject is available from the Prevention of Deterioration Center of the National Academy of Sciences (66). Also available from the Prevention of Deterioration Center is a bibliography of 144 references, most of these with abstracts, on microbial corrosion of metals (67). Another compilation of references, with particular reference to fuel contamination, has been published by ASTIA (51). A summary of Soviet work is available from AID, Library of Congress (24).

A few recent articles on the fundamentals of microbial attack on hydrocarbons have been included in the bibliography (25, 35, 45, 54, 55, 56, 65, 70, 83, 91, 92, 93). This does not, of course, represent anything like complete coverage, as the literature on this subject is becoming rather extensive. It has not been attempted to cover the general literature on oil-field microbiology, nor on microbial action on "soluble oils" or other industrial emulsions. However, a few references have been included on bacterial corrosion and slime in refinery and oil-well operations (27, 28, 41, 72, 73, 74, 75, 81, 89).

Of the remaining references in this section, most are concerned directly with the microbiological aspects of jet fuel contamination. Reviews and contributions to the literature have come from many sources including Lockheed(43), Olmsted AFB (88), Naval Research Laboratory (60), British Petroleum Research Centre (32), and Australian Defense Standards Laboratories (47-49), British Naval Aircraft Materials Laboratory (62, 63), General Dynamics (86), U. S. Chemical Corps Biological Laboratories (34), Melpar (31), Monsanto (77, 78), ASD (38), and Quartermaster Research and Engineering Center (69). A recent paper by Swatek (81) discusses the role of organisms in modifying and utilizing the environment to permit the flourishing of a continually changing population, and also the relation of these and other processes to practical field problems of fuel handling and storage. Microbial contamination of diesel fuels is discussed by Wright and Hostetler (90). A summary of earlier work on microbiological sludge in jet fuel, including identification of the microorganisms, has been given by Prince (68). The effect of microbial growth on the surfactant properties of jet fuels has been discussed in recent papers by Krynitsky (58) and by Krynitsky and McLaren (59). This work indicated that the growth had no adverse effects on fuel surfactant properties as measured by the "surfactant test" or a modified separometer test.

Microbial corrosion problems were touched upon in many of the references cited previously. In addition, several references were found dealing primarily with microbial corrosion of fuel tank materials (23, 29, 50, 84, 86, 87).

Early Air Force work in fuel microbiology is described in a report by Bakanauskas (26). Microbiological examination of samples from Ramey AFB and Eglin AFB, including isolation and identification, is described in (36). Current Air Force-sponsored work at Monsanto has produced three progress reports (77-79) giving a comparison of 23 fuels and various pure hydrocarbons in their susceptibility to microbial attack. Attempts are also being made to develop a VPC method to detect composition changes in fuels due to microbial attack.

An interesting method for detecting microbial contaminants in JP-4 has been described by George (46). The method, which is based on absorption of the carbon dioxide produced by the organisms, gave good qualitative results.

A useful manual, setting forth proposed procedures for the sampling and microbiological examination of contaminated fuels, has been prepared by the Society for Industrial Microbiology(76).

Of the reports describing microbiocides or microbial control agents for use in jet fuels, probably the earliest is that of Bakanauskas(26). This

work indicated that additives approved for JP-4 fuel at that time (gum and corrosion inhibitors) were not bacteriostatic agents, and some of them furnished nutrient. It was found that a 1.5 - 2.0% concentration of sodium tetraborate in the water bottoms would arrest growth. Subsequently, large-scale trials of this inhibitor proved disappointing, and it was thought that microorganisms had adapted to survive and grow under these conditions. Further work was reported by Churchill (37, 39) in isolating and identifying microorganisms from bulk fuel storage tanks and developing chemical kill or control agents. The three materials recommended for trial were tributyltin acetate, 2-nitroresorcinol, and β-nitrostyrene. In a recent report from General Dynamics (64), eighteen mechanical techniques are analyzed theoretically for use in killing, removing or controlling microorganisms in jet fuel. Two methods were evaluated experimentally: Killing microorganisms with radiofrequency was not very successful, and removal of microorganisms from jet fuel by fine filtration was successful only when dry fuel was used.

Work on inhibitors has also been reported from the Naval Research Laboratory (57). The use of organoboron compounds has been discussed in two papers (40, 41) and patent (42) of Standard Oil of Ohio, and also in a patent of U. S. Borax and Chemical (85). The use of nitroparaffins as bacterial growth inhibitors for cutting-oil emulsions is discussed by Bennett and Futch of the University of Houston (30). In two patents (71, 82), other inhibitors are discussed.

Methods for removing organic contaminants from petroleum hydrocarbons through the action of selected microorganisms are discussed in another patent (53).

D. Fuel Handling Methods and Facilities

Very little material fell into this general classification, since most of the items of interest either dealt with filters and filter-separators (see following section) or with more general fuel handling problems. Of the diverse references in this section, one (94) concerns testing of the type MH-2 Filter Meter Hose Trailer and subsequent recommendations of modifications to improve the overall operational suitability of the unit. A group of five API bulletins (95-99) covers many aspects of commercial fuel handling, including planning and installation of airport fuel systems, storage and handling of jet fuels at airports, fueling turbine-powered aircraft, and the use of internal floating covers for fixed-roof tanks to reduce evaporation loss.

A report from the RCAF (100) concerns methods of loading refueling trucks to prevent the access of contaminants. In this work, which was carried out by the RCAF Central Experimental and Proving Establishment, a

sealed, top-loading system was devised. The final article of this section deals with a bottom-laid ship-to-shore pipeline system developed by the U.S. Navy (101).

E. Filter-Separators

This material includes information on filtration and water coalescence in handling aviation fuels. Various types of filters and coalescing devices are covered by patents (107, 110, 111, 113, 114, 117, 121, 122). Although the literature had been searched about two years ago for material pertaining to coalescence of water in fuels, it is probable that some important patents have been missed, since the search was not directed primarily toward filtration.

Bench-scale and single-element test facilities and procedures for evaluating filter-separators are described in reports by A. D. Little (118), Southwest Research Institute (115, 116), and Detroit Testing Laboratory (108). The A. D. Little work was directed at an evaluation of the variables affecting filter-separator performance and the development of standard test contaminants. The SwRI work was aimed primarily at evaluating the effects of corrosion inhibitors on filter-separator performance and correlation with separometer test results. Test facilities and methods are also described in two British papers (102, 106).

The development and testing of a standard 20-gpm filter-separator are described in three Army reports (104, 105, 112). A more general picture of the Army ERDL filter-separator development program is given in references (109) and (123). Reference (109) describes the standard DOD filter-separators in some detail and lists the locations at which these units are in operation.

Evaluation tests of coalescer elements for filter separators are described in two Navy reports (119, 120).

One article on a self-cleaning filter for jet fuel decontamination (124) is included in this section. This is a wire-cloth unit using diatomaceous earth precoat; it is installed in the receiving end or a 4" pipline from Richfield Oil to Douglas Aircraft. Apparently there is some question on whether the unit will remove water, as a cartridge-type coalescer is placed downstream from the filter. The filter unit is said to bring contamination level consistently below 1 mg/gal.

F. Various Methods for Fuel Decontamination

A survey of various methods for removing water from aviation fuels was reported by A. D. Little (129) in 1958. Some experimental work was

performed on coalescers and separators, and also on dry-gas stripping. Centrifuging, electrostatic precipitation, and vacuum stripping were already under evaluation by the Navy. Gas stripping was the method recommended for further evaluation. Another, more recent report by A. D. Little (130) describes electrostatic, ultrasonic, centrifuge, brine extraction, adsorption, absorption, distillation, and dry-gas stripping methods of water removal, as well as the use of chemical additives and the application of brine extraction. Centrifuging is discussed in some detail in a report of the Brooklyn Navy Yard Material Laboratory (126).

A feasibility study on the removal of water from B-52 and KC-135 aircraft tanks was reported by Bendix (125). The studies were directed toward both water and ice removal, using a circulating system.

Two other references on fuel decontamination consisted of a discussion of a vacuum-flash dehydration method for removing dissolved water from jet fuels and middle distillates (127) and a description of a Go - NoGo fuel quality gage (128).

G. Contamination Analysis and Detection

The following items of interest were found:

Shell (131, 136). Determine water by reaction with CaC_2, followed by determination of C_2H_2 by infrared spectrometry.

British Petroleum (132). Determine free water by turbidity ("Aquascan").

Consolidated Electrodynamics (133, 134, 137). Determine total and dissolved water by coulometric analysis, solids by turbidity measurements.

Engle and Moebes (135). Determine total water in transformer oils by modified Karl Fischer method.

Bowser Ltd. (138). Determine free water by coalescence, followed by distillation.

Garrel (139). Method detects rapidly free water in fuel by color change.

Naval Research Lab. (140). Determine total water by stripping and absorption.

Socony (141). Detect free water by use of dye.

WADD (142). Comparison of Millipore and Whatman filters.

Ohio State (143). Water detection in fuels (1949 report).

WADC (144). Determine water in rocket fuels (hydrazines, etc.) by capacitance method.

Navy AEL (145). A "contaminated fuel detector" based on light transmittance through a Millipore filter.

Radiation Counter Labs (146). Attempts to measure water by neutron activation, and solids by gamma ray density gaging.

Purolator (147). Indicator device for filter units (no details).

Navy EES (148). Optical methods.

U. S. Government (149). Indication of water in fuel by the fluorescence of treated filters under ultraviolet light.

United Research (150, 151). On-line contamination indicator for water and solids, based on differences in dielectric constant.

In addition to the references given here, the literature contains a considerable amount of material on modified Karl Fischer and related methods for water determination; in general, these were not included in this survey.

H. Water Solubility and Fuel Dehydration

Relatively little information is available in the Western literature on the solubility of water in hydrocarbons and the equilibrium and dynamic relationships between water content of hydrocarbons and the gas phase. Solubilities may be calculated from equations given by Hibbard and Schalla (154) in 1952; these results are probably of sufficient accuracy for most engineering purposes. Studies of solubility equilibria and changes in water content were reported by Crampton, Finn, and Kolfenbach (153) and by Caddock and Davies (152). Other studies of this nature, with particular emphasis on the removal of water from fuels by gas stripping, were reported by Krynitsky (155, 156).

It is believed that this scarcity of information is real, i.e., no really significant material in the Western literature has been overlooked. Soviet authors have given considerable attention to this question.

I. Water Separometer

Three reports (157, 158, 159) on the development and evaluation of the CRC water separometer are included here. Additional information on this apparatus, including correlation with single-element filter-separator tests, is given in references (115, 116).

J. Aircraft Fuel System Icing

General information on the Boeing 707 fuel system, with particular reference to icing problems and anti-icing measures, is given in reference (160). A Boeing report (162) described the results of their fuel icing investigations. It should be mentioned that there are numerous Boeing reports on this subject that were not included in the present survey and bibliography. Convair's work on fuel system icing is described in reference (165). Early research work on ice formation in hydrocarbons at Oklahoma A&M was reported in 1953 (163); this is an excellent basic study of the problem. Further studies and test method development were reported in 1960 by Armour Research Foundation (164). A CRC report discusses techniques for studying jet fuel icing problems (161).

No organized search was made for material on ice formation in fuels and in aircraft fuel systems, and it is probable that much more information may exist in the literature.

K. Anti-Icing Additives

The literature on anti-icing additives for jet fuels is all of comparatively recent origin, and it is believed that our coverage is complete. There is also a considerable body of information on anti-icing additives for gasolines, for protection against carburetor icing as well as tank and line freeze-ups. Carburetor icing additives have not been included in this survey, except in cases in which they have appeared to be of potential interest in jet fuel applications. Such compounds in this category include isopropyl ether (166), morpholine oleate (168), aliphatic diols (169), dimethylformamide and glycol diborates (173), monoalkyl ethers of mono- or diethylene glycol (176), and tris(hydroxymethyl)aminomethane and its derivatives (177). It should be noted that the glycol ethers represent the general class of materials found most useful in jet fuels. Originally it had been planned to use a diethylene glycol monoether as the jet fuel anti-icing additive. The use of monoalkyl ethers of mono-, di-, tri-, and tetraethylene glycols as jet fuel anti-icing additives is covered by Phillips patent (178). Another Phillips patent (183) describes the use of a mixed additive - a glycol and a glycol ether - in JP-4 fuel.

Two references (170, 171) have been found on elastomer compatibility tests using Phillips additive 52. Subsequently, the 55MB additive, which contains a

minor proportion of glycerin, was adopted. All of the subsequent work on anti-icing additive in jet fuel refers to this material. The status of tests on this additive was reported to the CRC Jet Fuel Icing Group in 1960 (184).

An investigation of various anti-icing additives was reported in 1960 by Midwest Research Institute (180, 181); this organization has also reported studies of the storage stability, partition coefficient, effect on topcoatings, and effect on bacterial growth of the 55MB additive (179). Interestingly, no inhibitory effect of the 55MB on bacterial growth was picked up in this work. An Esso patent (172) describes anti-icing compounds for improving petroleum distillate fuels (b. 90-550°F).

An investigation of various additives to remove or tie up water by chemical reaction was reported by A. D. Little (175).

Along with the large-scale use of the 55MB additive in 1962 military procurements of JP-4, some information has appeared in the literature relevant to blending and analysis of this material (167, 174, 182). The analytical method described in reference (174) is based on freezing point of a water extract and is somewhat simpler than the present standard titration or color-comparison methods.

L. Aircraft Fuel Tanks and Coatings

Two of the reports referenced previously (170, 171) deal with the compatibility of coatings with Phillips additive 52. Work has also been performed at the University of Dayton (193) on the compatibility of elastomers with 55MB additive. A considerable amount of work has been done by Boeing on aircraft tank coating materials, and one reference (186) is included here. British work on this subject is reported in reference (187). Another coating evaluation (this one relating to shipboard tanks rather than aircraft tanks) was reported by the Navy Aeronautical Materials Laboratory (185). A zinc-based coating was evaluated in this work.

Development of an accelerated test procedure for fuel-resistant coatings has been reported by Aberdeen Proving Ground (190).

A Battelle report (188) presents results of an investigation of the resistance of 19 commercial coatings to a mixture of five of the more active elastomer-degrading species, the effectiveness of various biocides, and the aluminum corroding tendencies of specific fuel-water-microorganism systems.

A description of Russian techniques in the application of anti-corrosion coatings to inner surfaces of tanks is described in reference (191).

IX. BIBLIOGRAPHY

FUEL CONTAMINATION PROBLEMS IN GENERAL

1. Anon, "Delta Recommends Closer Surveillance of Aviation Fuel," Aeroplane Com Aviation News, 10 Jan 1963, p. 5.

2. Bert, J. A. (Cal. Research), "Trace Surfactants in Jet Fuel Cause Filter-Separator Problems," DOD Symposium on Contamination of Jet Fuel, Washington, D. C., 13-14 Sep 1961.

3. Brooks, D. B. (DOD), "Military Research on Jet Fuel Contamination," 28th Midyear Meeting, Am Petrol Inst, Div Refining, Philadelphia, 13 May 1963.

4. Burk, F. C., "Jet Fuel Problems in Military Aircraft at Ramey Air Force Base, Puerto Rico," DOD Symposium on Contamination of Jet Fuel, Washington, D. C., 13-14 Sep 1961.

5. Coker, G. T., Heiple, H. R., and Davies, R. G. (Shell), "Can We Define Aircraft Turbine Fuel Cleanliness Requirements?" SAE Preprint 47T, N. Y. Meeting, 31 Mar 1959.

6. Digman, W. J. (Douglas Aircraft), "Effects of Fuel Contamination on Corrosion of Aircraft Fuel Systems," SAE Preprint 575A, Los Angeles Meeting, 8-12 Oct 1962.

7. Digman, W. J. (Douglas Aircraft), "Fuel Contamination - Its Effect on Turbine-Powered Aircraft," Aerospace Maintenance Safety, Aug 1963, pp. 3-13.

8. Dukek, W. G. (Esso), "Fuel Contamination Studies," DOD Symposium on Contamination of Jet Fuel, Washington, D. C., 13-14 Sep 1961.

9. Dunnam, M. P. (ASD), "USAF Comments," (on contaminated fuel), DOD Symposium on Contamination of Jet Fuel, Washington, D. C., 13-14 Sep 1961.

10. Harris, D. N. and Coker, G. T. (Shell), "Experience in Turbine Fuel Quality Control," World Petroleum Congress, New York, 1959, Technical Papers Sec VIII, Paper 11.

FUEL CONTAMINATION PROBLEMS IN GENERAL (Cont'd)

11. Little, W. S., Jr. (Shell), "Turbine-Powered Aircraft Demand New Fuel Handling Techniques," SAE Preprint 99, N. Y. Meeting, 2-5 Apr 1957.

12. Loeser, C. E., Love, D. D., and Ogston, A. R. (Esso), "The Control and Measurement of Cleanliness Quality in Turbo Fuel," SAE Preprint 89C, Los Angeles Meeting, 29 Sep 1958.

13. London, S. A., "Air Force Programs in Fuel Microbiology," Aerospace Med Labs, AMRL Memo M-24, Jan 1963.

14. Perel, J. M., "Research and Development on the Copper Contamination of JP-5 Fuel by 90-10 and 70-30 Copper-Nickel Alloys," Material Lab, N. Y. Naval Shipyard, Brooklyn, Final Tech Rept, 21 Nov 1957. ASTIA No. AD-156, 659.

15. Prevention of Deterioration Center (Natl Acad Science's), Proceedings on Jet Fuel Microbiology and Corrosion Conference, 9-10 Apr 1962.

16. Rogers, J. D., (duPont), Krynitsky, J. A. (NRL), and Churchill, A. V. (ASD), "Jet Fuel Contamination: Water, Surfactants, Dirt, and Microbes," SAE Preprint 583C, Los Angeles Meeting, 8-12 Oct 1962.

17. Schab, H. W., "Problems Associated with Water Contaminated Jet Fuels," J Am Soc of Naval Engrs, Vol 72, No. 1, Feb 1960, p 41.

18. Schwartz, F. G. and Eccleston, B. H., "Survey of Research on Thermal Stability of Petroleum Fuels," U. S. Bur Mines Info Circ 8140, 1962.

19. Shell Oil Company, "Jet Fuel Contaminants and Their Significance," DOD Symposium on Contamination of Jet Fuel, Washington, D. C., 13-14 Sep 1961.

20. Singleterry, C. C. (Navy BuWeps), "Navy Experience with Water Contamination in JP-5 Fuel," DOD Symposium on Contamination of Jet Fuel, Washington, D. C., 13-14 Sep 1961.

21. Sutton, A. L., "Orenda Experience with Service Fuels," SAE Preprint 47S, N. Y. Meeting, 31 Mar 1959.

22. Totman, R. E. (United Air Lines), "One Airline's Experience with Trace Impurities in Turbine Fuel," DOD Symposium on Contamination of Jet Fuel, Washington, D. C., 13-14 Sep 1961.

MICROBIAL CONTAMINATION AND CORROSION

23. Abernathy, H. D. (Editor), "Fuel Tank Corrosion," Lockheed Service News, No. 29, Jul-Aug 1961.

24. Aerospace Info Div, "Bacterial Species Harmful to Petroleum Products in Storage," Library of Congress, AID Rept S-63-26, 21 Feb 1963.

25. Ali Khan, M. Y., Hall, A. N., and Robinson, D. S., "Microbial Transformation of n-Octane into Dicarboxylic Acids," Nature, Vol 198, 1963, p 289.

26. Bakanauskas, Sam, "Bacterial Activity in JP-4 Fuel," WADC TR 58-32, Mar 1958, ASTIA No. AD-151, 034.

27. Baumgartner, A. W. (Bradford Labs), "Sulfate-Reducing Bacteria," (detection and control), Oil Gas J, 11 Feb 1963, p 128.

28. Baumgartner, A. W. (Bradford Labs), "Sulfate-Reducing Bacteria - Their Role in Corrosion and Well Plugging," Producers Monthly, Vol 26, No. 7, 1962, pp 2-5.

29. Baumgartner, A. W., "Microbial Corrosion - What Causes It and How Can It be Controlled," J Petr Tech, Vol 14, 1962, pp 1074-8.

30. Bennett, E. O. and Futch, H. N. (Univ. of Houston), "Nitroparaffin Inhibitors for Cutting Fluids," Lubrication Eng. Vol 16, 1960, pp 228-30.

31. Blanchard, G. C., "Mechanism of Microbiological Contamination of Jet Fuel and Development of Techniques for Detection of Microbiological Contamination," Melpar Inc. First Quarterly Progress on Contract AF 33(657)-9186, 1 Jun 1963.

32. British Petroleum Research Centre, "Petroleum Microbiology - Some Effects of Microorganisms on Petroleum Operations and Refined Products," BPRC Tech Memo No. 120, 084, 6 Mar 1961.

33. Calvelli, E. A., "Don't Blame the Bacteria," SAE Preprint 749C, Los Angeles Meeting, 23-27 Sep 1963.

34. Chemical Corps Biological Labs, "Microbiological Contamination of JP-4," Summary Rept, 2 Jan 1962.

35. Chouteau, J., Azoulay, E., and Senez, J. C. (CNRS Labs, Marseille, France), "Bacterial Degradation of Paraffin Hydrocarbons. IV. Infrared Spectrophotometric Identification of 1-Heptene Produced from Heptane by Nonproliferating Suspensions of Pseudomonas Aeruginosa," Bull Soc Chim Biol, Vol 44, 1962, pp 671-7.

36. Churchill, A. V., "Microbiological Examination of Jet Fuel-Water Samples Ramey and Eglin Air Force Bases," ASD-TDR-62-361, Jul 1962. ASTIA No. AD-285, 002.

37. Churchill, A. V., "Research on Microbiological Sludge Inhibitors," ASD-TDR-62-368, Apr 1962. ASTIA No. AD-284, 183.

38. Churchill, A. V. (ASD), "Microbial Fuel-Tank Corrosion: Mechanisms and Contributory Factors," Mater Protect, Vol 2, No. 6, Jun 1963, pp 18-20, 22-3.

39. Churchill, A. V. and Leathen, W. W. (Gulf), "Development of Microbiological Sludge Inhibitors," ASD TR 61-193, Jun 1961. ASTIA No. AD-263, 009. Also in: DOD Symposium on Contamination of Jet Fuel, Washington, D. C., 13-14 Sep 1961.

40. DeGray, R. J. and Killian, L. N. (Std Oil Ohio), "Bacterial Contamination of Refined Petroleum Products," Am Chem Soc Div Petr Chem Preprints, Vol 5, No. 1, 1960, pp 43-51.

41. DeGray, R. J. and Killian, L. N. (Std Oil Ohio), "Bacterial Slime and Corrosion in PetroleumProduct Storage," Ind Eng Chem, Vol 52, No. 12, 1960, pp 74A-76A.

42. DeGray, R. J. and Killian, L. N. (Std Oil Ohio), "Inhibiting Microbiological Action during Storage of Hydrocarbons Such as Kerosine," Belgian Pat 609, 486, 24 Apr 1963; U. S. Appl 24 Oct 1960.

43. Donahue, T. B., "Microbiological Fuel Contamination and Corrosion," Lockheed Field Service Digest, Vol 7, No. 5, Mar-Apr 1961.

44. Fuhs, G. W., "The Destruction of Hydrocarbons by Microbes," Archiv für Mikrobiologie, Vol 39, 1961, pp 374-422. English translation, U. S. Dept Commerce OTS, No. JPRS 14, p 362.

45. Fincher, E. L. (Univ. of Ga.), "Bacterial Utilization of Ethoxy Glycols," Univ Microfilms (Ann Arbor, Mich.), Order No. 62-5403, 220 pp; Dissertation Abstracts, Vol 23, 1962, p 1875.

46. George, Marilyn E., "Detection of Microbial Contaminants in JP-4 Fuel," Aerospace Med Res Labs, AMRL Memo M-26, Jan 1963.

47. Hazzard, G. F., "Contribution to Discussion at SAE, Detroit, 14-18 Jan 1963," Defence Stds Labs, Melbourne, Australia. Comments and Discussions of paper by Frank C. Swatek (SAE Paper 651A).

48. Hazzard, G. F., "Fungal Growths in Aviation Fuel Systems," Dept of Supply, Australian Defence Scientific Service, Defence Standards Lab, Rept 252, Part 1, Aug 1961. Also in: DOD Symposium on Contamination of Jet Fuel, Washington, D. C., 13-14 Sep 1961.

49. Hazzard, G. F. and Kuster, E. C., "Fungal Growths in Aviation Fuel Systems," Dept of Supply, Australian Defence Scientific Service, Defence Standards Lab, Rept 252, Part 2, Dec 1962.

50. Hendy, N. I., "The Effect of 'Panacide' Sodium and Aspergillus Spp. on the Corrosion of Mild Steel Immersed in Glycerin/Water Hydraulic Fluid," Admiralty Materials Lab Rept No. A/13(c), Great Britain.

51. Henery, R. B., "Compilation of References on Microbiological Contamination of Fuels," ASTIA, AD-266,000, 1 Nov 1961.

52. Hitzman, D. O., Shotton, J. A., and Alquist, H. E., "Biocidal Effects of PFA 55MB," SAE and ASNE Paper 683D, Washington, D. C. Meeting, 8-11 Apr 1963.

53. Hitzman, D. O. (Phillips), "Removal of Organic Contaminants from Petroleum Hydrocarbons through the Action of Microorganisms," U. S. Pat 3,069,325, 18 Dec 1962.

54. Ishikura, T. and Foster, J. W. (Univ. of Texas), "Incorporation of Molecular Oxygen during Microbial Utilization of Olefins," Nature, Vol 192, 1961, pp 892-3.

55. Kester, A. S. and Foster, J. W. (Univ. of Texas), "Diterminal Oxidation of Long-Chain Alkanes by Bacteria," J Bacteriol, Vol 85, 1963, pp 859-69.

56. Kester, A. S. (Univ. of Texas), "The Oxidation of Hydrocarbons by Microorganisms," Univ Microfilms, Order No. 62-516, 133 pp; Dissertation Abstr 22, 3350 (1962).

57. Klemme, D. E. and Leonard, J. M., "Microbial Inhibitors for Systems of Jet Fuel and Water," Naval Res Lab, Rept 5501, 31 Aug 1960. ASTIA No. AD-244, 511.

58. Krynitsky, J. A., "Some Effects of Microbial Growth on the Surfactant Properties of Jet Fuels," Am Chem Soc, Div of Microbial Chem, Atlantic City Meeting, 13 Sept 1962.

59. Krynitsky, J. A. and McLaren, G. W. (USN Res Lab), "Some Effects of Microbial Growths on Surfactant Properties of Fuels," Biotechnol Bioeng, Vol 4, 1962, pp 357-67.

60. Leonard, J. M. and Klemme, D. E. (NRL), "Fungi in Fuel," Rept of NRL Progress, PB 181076, Sep 1962.

61. Naval Air Material Center, "Boeing T50-BO-4 Engine Fuel Control System - Evaluation Using Contaminated Fuel," ASTIA No. AD-265, 024L.

62. Naval Aircraft Materials Lab, "Fungal Contamination of AVCAT Fuel Systems, Laboratory Examination of Fungicidal Preparations," NAM Lab Rept F/ECH/3, R. N. Aircraft Yard, Fleetlands, 1961.

63. Naval Aircraft Materials Lab, "Fungal Contamination of the AVCAT Fuel Systems of HM Aircraft Carriers, Victorious, Eagle, Albion and Centaur," NAM Lab Rept F/ECH/2, ACC 2120-61, Royal Naval Aircraft Yard, Fleetlands, 1959.

64. Owen, H. P., Carroll, M. T., Hedrick, H. G., Albrecht, W. T., and Pritchard, D. J., "Mechanical Techniques for Killing, Removing, or Controlling Microorganisms in Hydrocarbon Fuels," ASD-TDR-63-242, 28 Oct 1963.

65. Phillips, U. A. and Traxler, R. W. (Univ. SW La.), "Microbial Degradation of Asphalt," Appl Microbiol., Vol 11, 1963, pp 235-8.

66. Prevention of Deterioration Center, "Bibliography on Microorganisms Affecting Petroleum and Petroleum Products Including Reports on Sulfate-Reducing Bacteria," Natl Acad Sci & Natl Res Council, 3 Aug 1961. ASTIA No. AD-265, 033.

67. Prevention of Deterioration Center, "Bibliography on Microbial Corrosion of Metals," Natl Acad Sci & Natl Res Council, Rept No. PDL-48074, 11 July 1963.

68. Prince, A. E. (Biomed Lab, WADD), "Microbiological Sludge in Jet Aircraft Fuel," Developments in Industrial Microbiology," Vol. 2, Plenum Press, 1961.

69. Rogers, M. R. and Kaplan, A. M. (Quartermaster Res & Engr Ctr), " A Field Survey of the Microbiological Contamination Present in JP-4 Fuel and 115/145 Avgas in a Military Fuel Distribution System," Microbiological Deterioration Series Report No. 6.

70. Rogoff, M. H., and Wender, I. (U. S. BuMines), "Oxidation of Aromatic Compounds by Bacteria," U. S. Bur Mines Bull 602, 1962.

71. Ryder, J. W., "Fuels Inhibited against Bacterial Growth," U. S. Pat 3, 044, 864, 17 July 1962.

72. Sherwood, P. W., "Protecting Gas-Plant Equipment from Bacterial Corrosion," Gas-Wasserfach, Vol 103, 1962, pp 1158-60.

73. Sherwood, P. W., "Watch Out for Bacterial Corrosion in the Refinery," Corrosion Technol, Vol 9, 1962, pp 211-14.

74. Sherwood, P. W., "Control of Bacteriological Corrosion in (Oil) Refineries," Corrosion, Anti-Corrosion, Vol 11, No. 2, 1963, pp 56-62.

75. Sherwood, P. W., "Watch Out for Bacterial Corrosion in Refineries," Werkstoffe Korrosion, Vol 14, 1963, pp 7-10.

76. SIM Committee on Microbiological Deterioration of Fuels, "Proposed Procedures for Microbiological Examination of Fuels," Soc Ind Microbiol Special Publ, No. 1, Jul 1963.

77. Smith, J. O., et al., "Effects of Selected Strains of Microorganisms on the Composition of Fuels and Lubricants," Monsanto Res Corp Quarterly Prog Rept No. 1 on Contract AF 33(657)-9814, 1 Sep 1962 to 30 Nov 1962.

78. Smith, J. O., et al., "Effects of Selected Strains of Microorganisms on the Composition of Fuels and Lubricants," Monsanto Research Corp Quarterly Prog Rept No. 2 on Contract AF 33(657)-9814, 15 Mar 1963.

79. Smith, J. O., et al., "Effects of Selected Strains of Microorganisms on the Composition of Fuels and Lubricants," Monsanto Research Corp Quarterly Prog Rept No. 3 on Contract AF 33(657)-9814, 17 Jun 1963.

80. Stormont, D. H., "Do Jet Fuel Bacteria Cause Slime, Corrosion," Oil Gas J, 3 Jul 1961, p 82.

81. Swatek, F. E., "Fundamentals of Microbiological Contamination of Liquid Hydrocarbon Fuels," SAE Paper 651A, Detroit Meeting, 14-18 Jan 1963.

82. Thompson, R. N., "Inhibiting Bacterial Growth," U. S. Pat 3,089,847, 14 May 1963.

83. Traxler, R. W. (Univ. of SW La.), "Microbial Degradation of Asphalt," Biotechnol Bioeng, Vol 4, 1962, pp 369-376.

84. Ward, C. B. (ASD), "Corrosion Resulting from Microbial Fuel-Tank Contamination," Mater Protect, Vol 2, No. 6, 1963, pp 10-12, 14, 16.

85. Willcockson, G. W., "Inhibiting Bacterial Activity in Petroleum," U. S. Pat 3,035,887, 22 May 1962.

86. Wilson, D. C., et al.,(General Dynamics), "Microbiological Corrosive Effects on Structural Materials Used in Aircraft Fuel Tanks," Prog Rept No. 1 on Contract AF 33(657)-8752, 15 Feb 1963.

87. Wilson, D. C., et al.,(General Dynamics), "Microbiological Corrosive Effects on Structural Materials Used in Aircraft Fuel Tanks," Prog Rept No. 2 on Contract AF 33(657)-8752, 15 May 1963.

88. Wilson, J. G. (Olmsted AFB), "Microbial Growth in Fuels and Fuel Systems," J Am Assoc Contamination Control, Vol 11, No. 1, 1962, pp 11-12.

89. Wright, C. C. (Oil Well Res., Inc.), "What We're Learning About Bacterial Corrosion," Oil Gas J, Vol 60, No. 26, 1962, pp 124-5.

90. Wright, R. H. (N. Y. Central RR) and Hostetler, H. F. (Std. Oil Ohio), "Microbiological Diesel Fuel Contamination," SAE Preprint 651B, Detroit Meeting, 14-18 Jan 1963.

MICROBIAL CONTAMINATION AND CORROSION (Cont'd)

91. Yamada, K., Takahashi, J., and Kobayashi, K. (Univ. Tokyo), "The Utilization of Hydrocarbons by Microorganisms," Agr Biol Chem, Tokyo, Vol 26, 1962, p 636.

92. Yamada, K., Takahashi, J., Kobayashi, K., and Imada, Y. (Univ. Tokyo), "The Utilization of Hydrocarbons by Microorganisms. 1. Isolation of Amino Acid-Producing Bacteria from Soil," Agr Biol Chem (Tokyo), Vol 27, 1963, pp 390-395.

93. Yamada, K., Takahashi, J., and Kobayashi, K. (Univ. Tokyo), "Utilization of Hydrocarbons by Microorganisms," Nature, Vol 198, No. 4885, 1963, p 1115.

FUEL HANDLING METHODS AND FACILITIES

94. AF Proving Ground Command, Eglin AFB, Fla., "Employment and Suitability Test of the Filter Meter Hose Trailer; Type MH-2," Final Rept.

95. American Petroleum Institute, "The Installation of Fixed Fuel Handling Equipment at Airports," API Bulletin 1502, Aug 1960.

96. American Petroleum Institute, "The Storage and Handling of Jet Fuels at Airports," API Bulletin 1503, Nov 1961.

97. American Petroleum Institute, "Airport Fueling Systems - Planning Criteria," API Bulletin 1505, Apr 1961.

98. American Petroleum Institute, "Fueling Turbine-Powered Aircraft," API Bulletin 1523, Second Edition, Apr 1963.

99. American Petroleum Institute, "Use of Internal Floating Covers for Fixed-Roof Tanks to Reduce Evaporation Loss," API Bulletin 2519, Nov 1962.

100. Heather, F. G., "Loading Truck Fueller," RCAF Central Experimental and Proving Establishment Rept No. 1506, Jan 1961. ASTIA No. AD-255, 247

101. Traffalis, J. J., "Ship-to-Shore Bulk Fuel Delivery System (Bottom Laid)," U. S. Naval Civil Engr Lab Tech Rept R-180, 31 Jan 1962. ASTIA No. AD-279, 462.

FILTER-SEPARATORS

102. Anon, "Fuel Filter Test House," Engineer (London), Vol 212, 1961, pp 366-7.

103. American Petroleum Institute, "The Filtration of and Water Removal from Aviation Fuels," API Bulletin 1501, Mar 1960.

104. Army Arctic Test Board, "Service Test of POL Filter/Separator 20 gpm," Army Arctic Test Board, Fort Greely, Alaska, 25 Apr 1960.

105. Army Aviation Board, "Service Test of the POL Filter/Separator, 20 gpm," Army Aviation Board, Fort Rucker, Ala.,1 Jul 1960.

106. Beynon, L. R. and Cranston, R. W., "Specification and Testing of Filters and Water Separators," Engineer (London), Vol 209, 1960, pp 331-7.

107. Daley, R. J. and Schaber, Donald R. (Bowser, Inc.), "Apparatus for Separating Water and Solids from Hydrocarbons," Ger Pat 1, 122, 651 (Cl 23b), 25 Jan 1962; U. S. Appl 6 Sep 1955.

108. Detroit Testing Lab, "Procedures for the Determination of the Particle Size Retention Characteristics, the Flow Resistance Characteristics, and the Dirt Handling Capabilities of Fuel Filters for Aircraft Jet Engines," DTL Rept 0607-E-1, 7 Jun 1955.

109. Estabrooke, J. C. and Stark, L. L., "Design, Development, and Evaluation of Military-Design Filter/Separators," Army ERDL, Rept 1716-TR, 29 Jun 1962.

110. Feinbau, Faudi G. m.b.H. (by Arnold Dornauf), "Filtering and Coalescing Device for Liquid Hydrocarbons," Ger Pat 1, 134, 785 (Cl 23b) 16 Aug 1962.

111. Fitzgerald, J. N., Gernhardt, J. W., and Redmond, O. C., (Fram Corp), "Separator for Water from Liquid Hydrocarbons," Ger Pat 1, 078, 721 (Cl 23b), Appl 24 May 1957.

112. Grant, M. G., "Development of Prototype 20-gpm Filter/Separator (A Proposed Standard Military Item)," Army ERDL, Tech Rept 1561-TR 15 May 1959.

113. Headrick, R. T. (Bowser, Inc.), "Filter (Water Separator) for Liquid Fuels," U. S. Pat 3, 048, 275, 7 Aug 1962.

114. Hersberger, A. B. (Atlantic Refining Co), "Removal of Water Haze from Immiscible Liquid," Can Pat 458, 556, 2 Aug 1949.

115. Johnston, R. K. and Cuellar, J. P. (Southwest Res Inst), "Effect of Jet Fuel Additives on Filterability and Water Separation Characteristics," ASD TR 61-345, Contract AF 33(600)-39425, June 1961. ASTIA No. AD-264, 607.

116. Johnston, R. K. and Cuellar, J. P. (Southwest Res Inst), "Service Test Evaluation of Filterability and Water Separation Characteristics of Jet Fuel," WADD TR 60-908, Vol 1 and 2, Contract AF 33(600)-39425, Jan 1961.

117. Kasten, W. (Bendix Corp), "Coalescer for the Separation of Water and Liquid Hydrocarbons," Ger Pat 1, 133, 783 (Cl 23b), Appl 30 Jul 1958, U. S. 8 Aug 1957.

118. Little, A. D., Inc., "Investigation of Parameters Affecting Aircraft and Missile Fuel Filtration," WADD TR 60-263, Contract AF 33(616)-6386, 1 Mar 1960. ASTIA No. AD-243, 251.

119. Naval Engineering Experiment Station, "Evaluation Tests of Bendix-Skinner 24-Inch Long Coalescer Element for Filter/Separators Used with JP-5 Fuel," EES Rept 020207E, 18 Jul 1957.

120. Naval Engineering Experiment Station, "Evaluation Tests of Richmond 24-Inch Long Coalescer Elements for Filter/Separators Used with JP-5 Fuel," EES Rept 020207H, 29 Jul 1957.

121. Purolator Products, Inc., "Separation of Water from Fuels," Brit Pat 892, 663, 28 Mar 1962, U. S. Appl 18 Mar 1960.

122. Robinson, J. W. (Fram Corp), "Gasoline Filter," Ger Pat 1, 044, 327, 20 Nov 1958.

123. Stark, L. L. (ERDL), "USAERDL Fuels Decontamination Equipment Development Program," DOD Symposium on Contamination of Jet Fuel, Washington, D.C., 13-14 Sep 1961.

124. Tygret, J. M. and Ulrich, R., "Terminal Filtering Cuts Dirt in Jet Fuel," Oil Gas J, Vol 59, No. 37, 11 Sep 1961, pp 106-10.

VARIOUS METHODS FOR FUEL DECONTAMINATION

125. Bendix Corp, "A Study of a Method for Removing Ice and Water from Strategic Aircraft Fuel Tanks," ASD TR 61-59, Contract AF 33(600)-41909, Nov 1961. ASTIA No. AD-271, 961.

126. Cohen, S. A. and Reifenberg, G. H., "Purification of Jet Fuel by Centrifugation," N. Y. Naval Shipyard, Final Rept, Proj 5319-34, 23 Sep 1958.

127. Graham, W. A., "Reduce Jet Fuel Problems by Removing Water," Hydrocarbon Processing and Petroleum Refiner, Vol 42, No. 9, Sep 1963, p 139.

128. Kasten, W., "Field Service Experience with the Bendix Go - No-Go Gage," Bendix Corp Presentation to American Airlines, 18 Jun 1963.

129. Little, A. D., Inc, "Methods of Removing Water from Aviation Fuels," USN Bur Aeronautics, Contract NoAS 56-986, 1 Dec 1958, C-60347. ASTIA No. AD-234, 986.

130. Reiman, P. A. (Arthur D. Little, Inc), "Investigation of Parameters Affecting Aircraft and Missile Fuel Filtration, WADD TR 60-263, Part II, May 1961. ASTIA No. AD-271, 466.

CONTAMINATION DETECTION AND ANALYSIS

131. Abrams, S. T. and Smith, V. N. (Shell Devel Co), "Trace Water Analyzer for Process Streams," Anal Chem, Vol 34, 1962, pp 1129-32.

132. Anon, "Measurement of Undissolved Water in Aviation Turbine Fuels," Engineer (London), 1961, p 950.

133. Cole, L. G., Gardiner,K. W., and Czuha, M. (Consol Electrodynamics Corp), "An Analyzer for Moisture in Jet Fuels," WADC Quarterly Progress Report CEC 1 on Contract AF 33(616)-6588, 15 Sep 1959.

134. Czuha, M. and Gardiner, K. W. (Consol Electrodynamics Corp), "An Analyzer for Moisture and Solids in Jet Fuels," WADD TR 60-401, Contract AF 33(616)-6588, Sep 1960. ASTIA No. AD-247, 114.

135. Engel, M. and Moebes, R., "Determination of Very Low Water Contents in Insulating Oils," (in German), Elektrie, No. 5, 1962, pp 157-9.

136. Forbes, J. W. (Shell Develop Co), "Trace Water Determination by Infrared Spectrometry," Anal Chem, Vol 34, 1962, pp 1125-8.

137. Gardiner, K. W. and Czuha, M. (Consol Electrodynamics Corp), "An Analyzer for Moisture in Jet Fuels," AF WADC Quarterly Progress Report CEC 2 on Contract AF 33(616)-6588, 15 Dec 1959.

138. Gardner, L. and Topol, G., "New Method for the Determination of Undissolved Water in Fuels," Mat Res & Stand, Vol 1, 1961, pp 112-15.

139. Garrel, P., "Rapid Detection of Free Water in Fuels," French Pat 1, 280, 099, 6 Apr 1962.

140. Garrett, W. D. and Krynitsky, J. A., "Determination of Water in Jet Fuels and Hydrocarbons," Naval Res Lab Rept 4997, 4 Sep 1957.

141. Levine, W. S. (Socony Mobil Oil Co, Inc), "Water Detection in Hydrocarbon Fuels," U. S. Pat 3, 041, 870, 3 Jul 1962.

142. Linder, P. C. (WADC), "Operational Limits for Solid Contamination in Jet Fuels Using Millipore Method," WADD TN 60-53, 25 Jan 1960. ASTIA No. 232, 177.

143. MacNevin, W., "Water Detection in Fuels," Ohio State U. Res Foundation, Final Rept, Contract W33-038-ac-16679 (17471), 30 Jun 1949.

144. Malone, H. E. and Melville, J. C., "Determination of Water in Rocket Fuels," WADC TR 59-28, 23 Jan 1959. ASTIA No. AD-208, 858.

145. Pichtelberger, J. R. (Navy, Aero Engine Lab), "Development and Use of the AEL Contaminated Fuel Detector," DOD Symposium on Contamination of Jet Fuel, Washington, D.C., 13-14 Sep 1961.

146. Plasterer, D. H. and Walter, V. W., "Test Method for Detecting Minute Concentrations, Water and Solids, as Contaminants in Jet Fuels," Radiation Counter Labs on Contract AF 33(616)-6587, Quart Rept No. 1, Jun-Sep 1959.

147. Scavuzzo, W. J. (Purolator Products, Inc), "Indicator Device for Filter Units," Brit Pat 887, 963, 24 Jan 1962.

CONTAMINATION DETECTION AND ANALYSIS (Cont'd)

148. Schatzberg, Paul, "Investigations of Three Optical Methods for Determining Contaminant Content in JP-5 Fuels," Naval Eng Exper Station Rept No. 620496C, 16 Feb 1959.

149. Thyrum, P. T., "Determination of Free Water in Hydrocarbon Fuels," U. S. Pat 3,066,221, 27 Nov 1962.

150. United Res Inc. "Aviation Fuel Contamination Indicator," Final Eng Rept on U. S. Navy Contract NOas-59-6121-F, 5 Jan 1961.

151. United Res Inc. "Developmental Model of Aviation Fuel Contamination Indicator," Summary Prog Rept on Contract NO(as)59-6121-f, 20 Jun 1959 - 31 Aug 1960. ASTIA No. AD-244,470L.

WATER SOLUBILITY AND FUEL DEHYDRATION

152. Caddock, B. D. and Davies, P. L. (Shell Ltd), "The Use of Tritium to Study the Solubility of Water in Hydrocarbon Liquids," J Inst Petr, Vol 46, 1960, p 391.

153. Crampton, A. B., Finn, R. F., and Kolfenbach, J. J. (Esso), "What Happens to the Dissolved Water in Aviation Fuels?" SAE Preprint 104, 7-12 Jun 1953.

154. Hibbard, R. R. and Schalla, R. L., "Solubility of Water in Hydrocarbons," NACA RM E52D24, Jul 1952.

155. Krynitsky, J. A., "Theoretical Considerations Governing the Dehydration of Fuels by Gas Blowing," Naval Res Lab, Memo Rept 684, Feb 1957.

156. Krynitsky, J. A. and Carhart, H. W., "The Exchange of Water between Hydrophobic Liquids and Air," Naval Res Lab Report 3874, 3 Dec 1951.

WATER SEPAROMETER

157. Coordinating Research Council, "Development of Research Technique for Assessing the Water Separation Characteristics of Fuels and Fuel-Additive Combinations," CRC Project No. CA-19-59, July 1961, Revised Sep 1961.

158. Krynitsky, J. A. and Garrett, W. D., "Development of the Water Separometer," Naval Res Lab Memo Rept 1105, Oct 1960. Also in: DOD Symposium on Contamination of Jet Fuels, Washington, D.C., 13-14 Sep 1961.

WATER SEPAROMETER (Cont'd)

159. Krynitsky, J. A. and Garrett, W. D., "The Separation of Water from Fuels. Part 1 - Development of Laboratory Evaluation Method," Naval Res Lab Rept 5685, 22 Aug 1961.

AIRCRAFT FUEL SYSTEM ICING

160. Brunton, F. K. and DeWeese, J. C. (Boeing), "The Effects of Kerosene Type Fuels on the Design and Operation of a Jet Transport," SAE Preprint No. 47R, N. Y. Meeting, Apr 1959.

161. Coordinating Research Council, "Evaluation and Development of Techniques for Studying Jet Fuel Icing Problems," Aviation Fuel, Lubricant, and Equipment Research Committee of the Coordinating Research Council, Inc, Apr 1962, Revised Dec 1962.

162. Dufur, C. W., Balbierz, R., Cheeseman, S., and Johnson, C., "Fuel Icing Investigation," Boeing Airplane Company, Document No. D3-2135, 14 Feb 1959.

163. Johnston, Irving, "Research Study of Ice Formation in Hydrocarbons," Okla A&M Research Foundation Final Rept on Contract No. AF 33(616)-18, Mar 1953, ASTIA No. AD-9308.

164. Langer, G. (Armour Res Foundation), "JP-4 Fuel System Icing," WADD TR 60-826, Oct 1960. ASTIA No. AD-253, 973.

165. McCafferty, J. and Carel, G., "Convair 880 Fuel System Test Program," SAE Preprint 107V, Los Angeles Meeting, 5-9 Oct 1959.

ANTI-ICING ADDITIVES

166. Barnum, R. E. (Esso), "Aviation Gasoline," U. S. Pat 2, 884, 315, 28 Apr 1959.

167. Brooks, K., "What Those New Jet Fuel Specs Mean to Refiners," Oil Gas J, Vol 60, No. 2, 8 Jan 1962, p 81.

168. Cantrell, T. L. and Peters, J. G. (Gulf Oil), "Non-Stalling Gasoline Fuel Compositions," U. S. Pat 2, 920, 944, 12 Jan 1960.

169. Esso R&E, "Deicing Additives for Motor Fuels," Brit Pat 824, 630, 2 Dec 1959.

170. Gariepy, G. A., "Effect of Phillips Fuel Additive 52 on the Rubber-Like and Plastic Components of Fuel Handling Equipment for Fixed Airfield Refueling Systems," Army ERDL, Termination Report on Project 8-53-03-420, May 1960. ASTIA No. AD-239, 398.

171. House, P. A. (Materials Central, WADD), "Compatibility of Elastomers with Fuel Anti-Icing Additive," WADD TN 60-300, Apr 1961.

172. Jaffer, J. H., Jr., "Jet Engine Fuel," U. S. Pat 3, 103, 101, 10 Sep 1963.

173. Jones, A. L., Howsmon, W. B., and Hughes, E. C., (Std. Oil Ohio), "Anti-Icing Additive," U.S. Pat 2, 958, 591, 1 Nov 1960.

174. Loomer, D. M. and Graham, A. L., "10-Minute, No-Chemical Method Determines Amount of Anti-Icing Additive in JP-4," Oil Gas J, 14 Jan 1963, p 82.

175. McCaully, R. J., Olds, W. F., and Reiman, P. A. (Arthur D. Little, Inc), "Investigation of Water-Reactive Chemicals for Anti-Icing Additives in Aviation Fuels," WADD TR 61-40, Contract AF 33(616)-7006, Mar 1961. ASTIA No. AD-256, 758.

176. McTurk, W. D., Lifson, W. E., and Duncan, G. W. (Esso R&E), "Glycol Ether Gasoline Additives," U.S. Pat 3, 061, 420, 30 Oct 1962.

177. Mills, I. W. (Sun Oil Co), "Anti-Icing Additives for Gasoline or Jet Engine Fuels," U.S. Pat 2, 906, 613, 29 Sep 1959.

178. Mitacek, Bill (Phillips Petrol), "Jet Engine-Fuel Additives for Prevention of Filter Plugging with Ice," U.S. Pat 2, 952, 121, 13 Sep 1960.

179. Netzel, D. A., Byerley, T. J., and Pollock, H. B. (Midwest Res Inst), "Effects of Anti-Icing Additives on Jet Fuel Properties," ASD TR 61-280, Contract AF 33(616)-7598, May 1961.

180. Netzel, D. A., Elliott, R. L., and Bechtle, G. F. (Midwest Res Inst), "A Study of JP-4 Additives: Their Chemical Correlation and Physical Parameters as Effective Anti-Icing Agents," WADD Tech Rept 60-226 Part II, Aug 1960.

181. Netzel, D. A. and Gadberry, H. M. (Midwest Res Inst), "Investigation of Anti-Icing Additives in JP-4 Fuel," WADD Tech Rept 60-226, Jan 1960.

182. Reed, E. E., "How and When to Inject Additive for Anti-Icing Jet Fuel," Oil Gas J, Vol 69, No. 2, 8 Jan 1962, pp 85-6.

183. Shotton, J. A., "Anti-Icing Additives for Hydrocarbon Fuels," U.S. Pat 3, 032, 971, 8 May 1962.

ANTI-ICING ADDITIVES (Cont'd)

184. Wright Air Devel Div, "Status of Tests on Phillips Fuel Additive No. 55MB," Letter from WADD-WWDSPF to CRC Jet Fuel Icing Group, 5 Oct 1960.

AIRCRAFT FUEL TANK COATINGS AND SEALANTS

185. Aero Materials Lab, "The Effect of Dimetcote No. 3 Coating on Jet Engine Alloys by Contamination of Aircraft Fuels," Naval Air Material Center Rept NAMC-AML-AE 4164.1, 24 Feb 1959.

186. Boeing Airplane Co. "Integral Fuel Tank Coating (Data Package No. 8)," Boeing Final Summary Rept No. 4 on Contract AF 33(616)-8141. ASTIA No. AD-279, 777.

187. Central Dockyard Lab, "Improved Coatings for Aviation Fuel Tanks in Aircraft Carriers-Series II," C D L Report No. P/8/59, H. M. Dockyard, Portsmouth, 1959.

188. Cooper, C. W., Kemp, H. T., and Kell, R. M. (Battelle), "Elastomers for Fuel Systems Containing Microorganism-Controlling Additives," RTD-TDR-63-4195, 31 Dec 1963.

189. House, P. A., "Improving the Resistance of Integral Fuel Tank Coating Material to Fuel Anti-Icing Additive," ASD TDR 62-262, Feb 1962.

190. LePera, M. E., "An Accelerated Test Procedure for Evaluating the Compatibility of Protective Coatings with Combustion Fuels," Coating and Chemical Lab, Aberdeen Proving Ground, Rept No. CCL-129 (DA Prof 593-32-007), 15 Aug 1962. ASTIA No. 285,028.

191. Lykov, M. V., Inozemtsev, I. D., and Karpova, V. M., "Anti-Corrosion Protection of Mobile Tanks for Petroleum Products," Joint Publications Research Service, San Francisco, California, 20 Feb 1963. ASTIA No. AD-402, 512.

192. McGregor, J. M., (Thermoline Co), "Microorganisms Fail to Grow in Furane Lined Jet Fuel Storage Tanks," Materials Protection, Vol 2, No. 6, Jun 1963, p 24.

193. Univ. of Dayton Res Inst, "Compatibility Test Data of Elastomers with Fuel Anti-Icing Additive, Phillips Petroleum Co No. 55MB," U. D. Tech Memo No. 153, AF 33(616)-30178, Jul 1961.

APPENDIX A

LABORATORY TEST METHODS

APPENDIX A

LABORATORY TEST METHODS

A. General

This section comprises a list of the chemical, physical, and microbiological test methods used in the analysis of samples taken at Air Force bases and in support of the experimental program at SwRI. Some of the methods are not covered by recognized standards, and detailed descriptions are given in these cases.

The following methods were used to examine fuel and water samples taken at Air Force bases:

Anti-icing additive in water - distillation-R.I. method
Chloride content of water - turbidimetric method
Particulate matter in fuels - ASTM Appendix X (1960)
Water separometer tests - FTMS-791a Method 3255T
Total counts - nutrient agar pour plates and Millipore filter method
Fungus counts - Seitz filter with Sabouraud's agar

The following methods were used in connection with the experimental program at SwRI:

Anti icing additive in water - distillation-R.I. or periodate-R.I.
Anti-icing additive in fuel - dichromate titration (FTMS-791a Method 5327-T) or freezing point
Water separometer tests - FTMS 791a Method 3255T (standard) or 3256 (modified)
Particulate matter in fuels - ASTM Appendix X (1960)
Water content of fuels - ASTM D1744-60T with KF-3 apparatus
Interfacial tension - ASTM D971-50
Total bacterial counts - TSA spread plates (Trypticase soy)
Sulfate reducers - API sulfate broth
Iron depositers - Waksman-Leathen medium
Gas formers - semiquantitative, lactose broth
Coliforms - EMB agar
Fungi - Rose Bengal-streptomycin agar; Sabouraud's agar

B. Anti-Icing Additive in Water

1. Distillation-R.I. Method

At the time this program was started, it was found that no really satisfactory method was available for the independent determination of glycerin and methoxyethanol content of water bottoms over a wide range of concentrations. Therefore, a method was developed on the basis of a controlled distillation to take the methoxyethanol and water overhead, after which the amount of methoxyethanol in the distillate was determined by standard refractive index curves. The detailed procedure is as follows:

> A 20-g sample of the test material is weighed into a 200-ml ASTM distillation flask which has been modified by the addition of a hemispherical glass joint to the end of the sidearm. The flask is then fitted with a stopper and glass tube extending down to the bottom. The flask assembly, including a stopper for the end of the glass tube and a blank joint for sealing the sidearm, is then weighed. A distillate receiver, consisting of a test tube or other trap of adequate capacity fitted with a hemispherical joint, is also weighed with seals or stoppers for both connections. The flask is then immersed as deep as possible in an oil bath at 340-350° F and immediately connected up to the receiver, which is immersed in an ice-water bath. The end of the inlet (bubbler) tube of the flask is left plugged. The apparatus is left in this condition until distillation has essentially ceased, as evidenced by cooling of the sidearm and the top portion of the receiver; this usually requires about 20-25 minutes. Then nitrogen is introduced through the bubbler tube for exactly 10 minutes at the rate of 1 liter/hour. During the last half of this period, a hot-air blower ("heat gun") is applied judiciously to the upper part of the flask and the sidearm to dry out the material condensed there and carry it over with the distillate. This step is critical, as excessive heating will drive some glycerin overhead. At the end of the 10 minutes, the flask is removed from the oil bath with the assembly intact; this is best accomplished by lowering the oil bath away from the flask. Nitrogen bubbling is continued while the flask cools. The flask is then disconnected from the receiver, and both parts of the assembly are stoppered and reweighed. The weight of the residue in the flask is taken to represent the amount of glycerin in the sample, and the distillate is assumed to consist of methoxyethanol and water. The relative proportion of methoxyethanol and water is determined from the refractive index, n_D^{25}, using a standard curve established for water-methoxyethanol mixtures, as shown in Figure 16. Distillation losses, which are very small, are calculated as water.

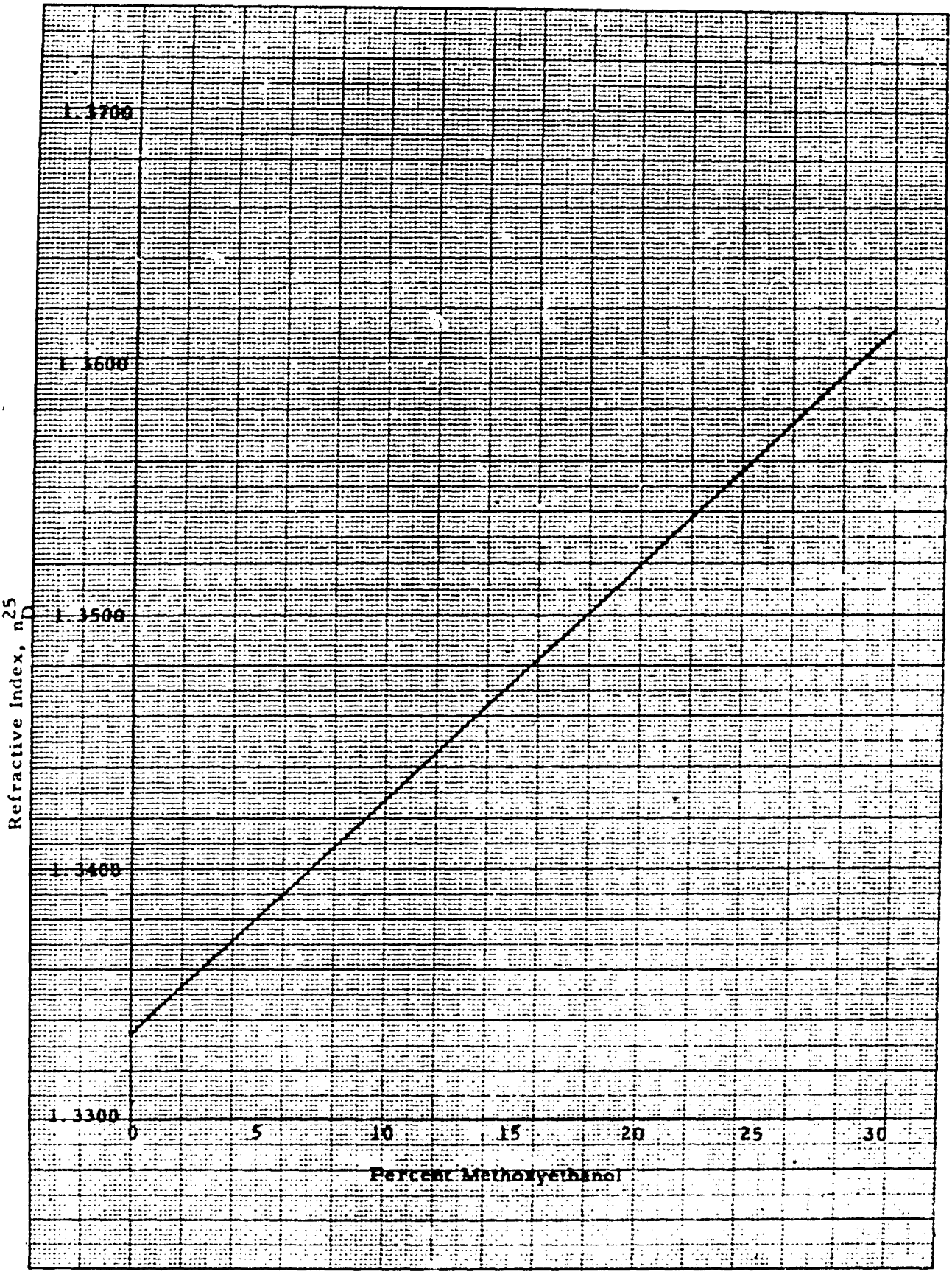


FIGURE 16. REFRACTIVE INDEX OF METHOXYETHANOL-WATER SOLUTIONS

In the higher ranges of glycerin content (5% or more), the method is accurate to within about 0.5%, based on checks against synthetic samples. In the lower ranges of glycerin content, the method is unreliable and tends to give high results on glycerin and correspondingly low results on methoxyethanol; the absolute error may reach 1 to 2%. The method is rather laborious and requires critical judgment of the operator. In application to field samples, errors would be introduced by any nonvolatile materials in the samples (which would be counted as glycerin) or by any foreign volatile material present in sufficient quantity to affect the R.I. of the distillate.

2. Periodate-R.I. Method

For the later work in this program, a periodate oxidation method for determination of glycerin was furnished through the office of the Air Force project engineer. This method had been adapted by Monsanto Chemical Company from the G. Frederick Smith Company's literature on periodate oxidimetry. The method as furnished is as follows:

Scope. This method is for the determination of glycerol in water bottom samples containing ethylene glycol monomethyl ether (methyl cellosolve).

Reagents and Materials. (1) Potassium iodide crystals (reagent grade). (2) Periodic acid solution (0.05 N). Dissolve 11.0 grams of reagent grade H_5IO_6 in 1 liter of distilled water. (3) Sulfuric acid (6 N), reagent grade. (4) Standard sodium thiosulfate solution. (5) Distilled water.

Procedure. (Note: Samples containing heavy suspended contamination should be filtered with a sintered glass crucible filter prior to conducting analysis.) (1) Pipet 1 ml of sample into a 500-ml iodine flask. (2) Pipet 25.00 ml of 0.05 N periodic acid solution (H_5IO_6) into each flask. Run 2 blanks using distilled water instead of sample. (3) Allow to stand for 1 hour. (4) Add 100 ml of distilled water to the flask. (5) Add 6 g of KI crystals, (6) Add 25 ml of 6 N sulfuric acid. (7) Titrate evolved iodine with standard sodium thiosulfate solution ($Na_2S_2O_3$).

Calculations.

$$\% \text{ Glycerol wt/vol} = \frac{(ml_B - ml_S)(N\ Na_2S_2O_3)(0.02302)(100)}{ml\ sample}$$

where ml_B = ml of $Na_2S_2O_3$ used for titrating blank,
ml_S = ml of $Na_2S_2O_3$ used for titrating sample, and
N = normality of standard sodium thiosulfate.

This method is based on the principle that periodic acid under these conditions gives a selective attack on compounds containing vic-hydroxy groups. Thus, it will attack glycerin or ethylene glycol, but not the monoethers of ethylene glycol (e.g., methoxyethanol).

The mechanism of the glycerin oxidation is as follows:

$$C_3H_8O_3 + 2\,HIO_4 = 2\,CH_2O + HCOOH + 2\,HIO_3 + H_2O$$

Glycerin + periodic acid = formaldehyde + formic acid + iodic acid + water

There are some problems involved in obtaining valid and accurate analyses by this method. Excess periodic acid is required in order to make the reaction quantitative. Only a part of the oxidizing capability of the periodic acid is used up in reaction with glycerin, since iodic acid is one of the reaction products. The remaining iodic acid, like the excess periodic acid, will oxidize KI and liberate iodine in the next step of the analysis. These factors dictate the use of relatively small differences between the blank titration and sample titration, as illustrated by the following:

Grams of Glycerin	Periodic Acid Unreacted, % of Original	Milliliters of 0.2N $Na_2S_2O_3$		
		Blank	Sample	Difference
0.002	96.4	48.32	47.89	0.43
0.005	91.0	48.32	47.23	1.09
0.008	85.6	48.32	46.58	1.74
0.011	80.2	48.32	45.93	2.39
0.044	20.8	48.32	38.77	9.55
0.055	0	48.32	36.38	11.94

Based on information in the literature, it appears that the analysis will be valid up to 0.044 gram of glycerin, but it is advisable to set a limit of 0.03 gram for extra margin. On the lower end, it is evident that the accuracy is poor in the region of 0.002 gram of glycerin, and probably 0.005 gram is a better minimum to observe. On this basis, it is necessary to adjust the sample size, where necessary, to keep the amount of glycerin taken for analysis within the limits of 0.005-0.03 gram. Fortunately, most of the samples encountered in the field are within this range, taking one-gram samples.

It should be noted that any organic substance present in the samples will interfere with the analysis if it is capable of reacting with periodic acid. For example, ethylene glycol (which is present as an impurity in

commercial methoxyethanol) will react with periodic acid. Since the allowable maximum content of ethylene glycol in methoxyethanol for anti-icing additive use is only 0.025%, interference by ethylene glycol in the glycerin determinations on water bottoms is highly unlikely. However, the presence of unknown, interfering organic substances in field samples must be accounted as a possibility. Any such organic materials would give results on glycerin that are too high. On the other hand, any oxidizing agent in the water bottoms (such as dichromate) would tend to give low results in the glycerin analysis.

Having determined the glycerin content of water bottoms sample, the methoxyethanol content can be estimated with reasonable accuracy from the refractive index of the total sample. Standard curves were prepared showing the variation of refractive index with glycerin and methoxyethanol contents, using fuel-saturated solutions to account for any effect of dissolved fuel on refractive index. A set of these curves is shown in Figure 17. Knowing the glycerin content from independent analysis, the methoxyethanol content can be read from the graph.

In applying this method to water bottoms samples in the current program, the glycerin contents were taken as the original "set up" concentrations, rather than the values obtained from analysis, since some trouble was being encountered in the glycerin determinations.

C. Anti-Icing Additive Content of Fuel Samples

The two methods used to determine the total content of anti-icing additive in the fuel-phase samples were the freezing point method of Loomer and Graham* and the standard dichromate titration method FTMS-791a Method 5327-T. For the purposes of this program, in the dichromate titration method, it was assumed that the anti-icing additive in the fuel phase consists of methoxyethanol only. In either method, no significant error would be introduced if the percentage of glycerin (relative to total additive) varied from 0 to 2%.

The dichromate titration method is well standardized and does not require further comment here.

The freezing point method is described by the following excerpt from the referenced article:

> Equipment. Materials required include a 1-liter separatory funnel; a ring stand and ring to fit the funnel; a 1-liter graduated cylinder; a 10-ml pipette; test tube; thermometer (range to include 25-30°F in 0.2°F divisions); wire-loop stirrer; two-hole stopper to fit test tube; and an ice-and-salt-water bath.

*Loomer, D. M. and Graham, A. L., "Ten-Minute, No-Chemical Method Determines Amount of Anti-Icing Additive in JP-4," Oil Gas J, 14 Jan 1963, pp 82-84.

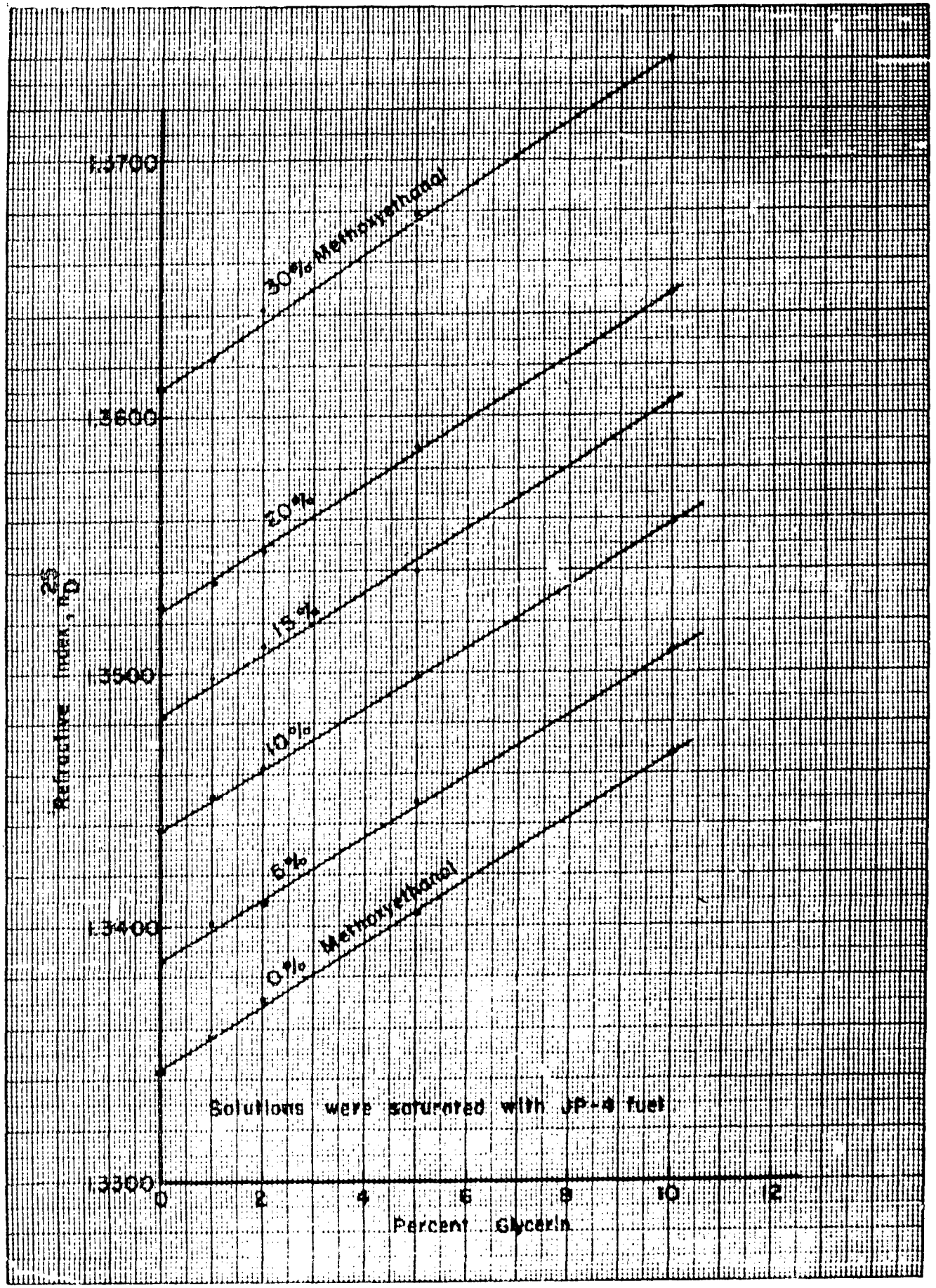


FIGURE 17 REFRACTIVE INDEX OF GLYCERIN-METHOXYETHANOL-WATER SOLUTIONS

Procedure. Put 800 ml of sample in the separatory funnel using a graduated cylinder or marks on the separatory funnel at the 800-ml level. Add 10.0 ml of tap water from a pipette. Stopper and shake vigorously for 3 minutes. Allow to settle until layers separate thoroughly (1 to 2 minutes).

Assemble freezing-point apparatus using a test tube stoppered with a two-hole stopper through which a thermometer and stirring loop are inserted. Draw off the water layer from the separatory funnel into the test tube. Insert the stopper, thermometer, and stirring loop so that the thermometer bulb is located in the center of the water.

Immerse the test tube in a crushed-ice-and-water bath to which some salt has been added. Stir the water continuously while observing the temperature change. It will fall to a minimum and then rise rapidly and remain constant for several seconds before falling again. The maximum temperature reached after the sudden rise is read to 0.1° F and recorded as the freezing point.

From the graph provided, read the volume percent of anti-icer corresponding to the freezing point obtained.

For the purposes of the experimental program, a calibration curve was established independently, relating the freezing point of the water extract to the content of anti-icing additive in the fuel phase (see Figure 18).

D. Chloride Content of Water

Following clarification of the field samples, dilution as required, and precipitation with silver nitrate, the chloride content was determined by turbidimetric comparison against standard samples. No attempt was made to remove interfering ions. The interfering ion most likely to be encountered in field samples is dichromate; however, this would have been readily evidenced by color of the precipitate. None of the samples examined were believed to contain dichromate. Halides other than chloride, if present, would also be precipitated and would add to the apparent chloride content. The occurrence of other halides in field samples in sufficient quantities to introduce any inaccuracy is regarded as highly improbable.

E. Interfacial Tension

In connection with the experimental program, interfacial tensions between fuel and the corresponding water bottoms were determined by the duNuoy ring method, ASTM D971-50, using a conventional tensiometer equipped for upward pull with a platinum ring.

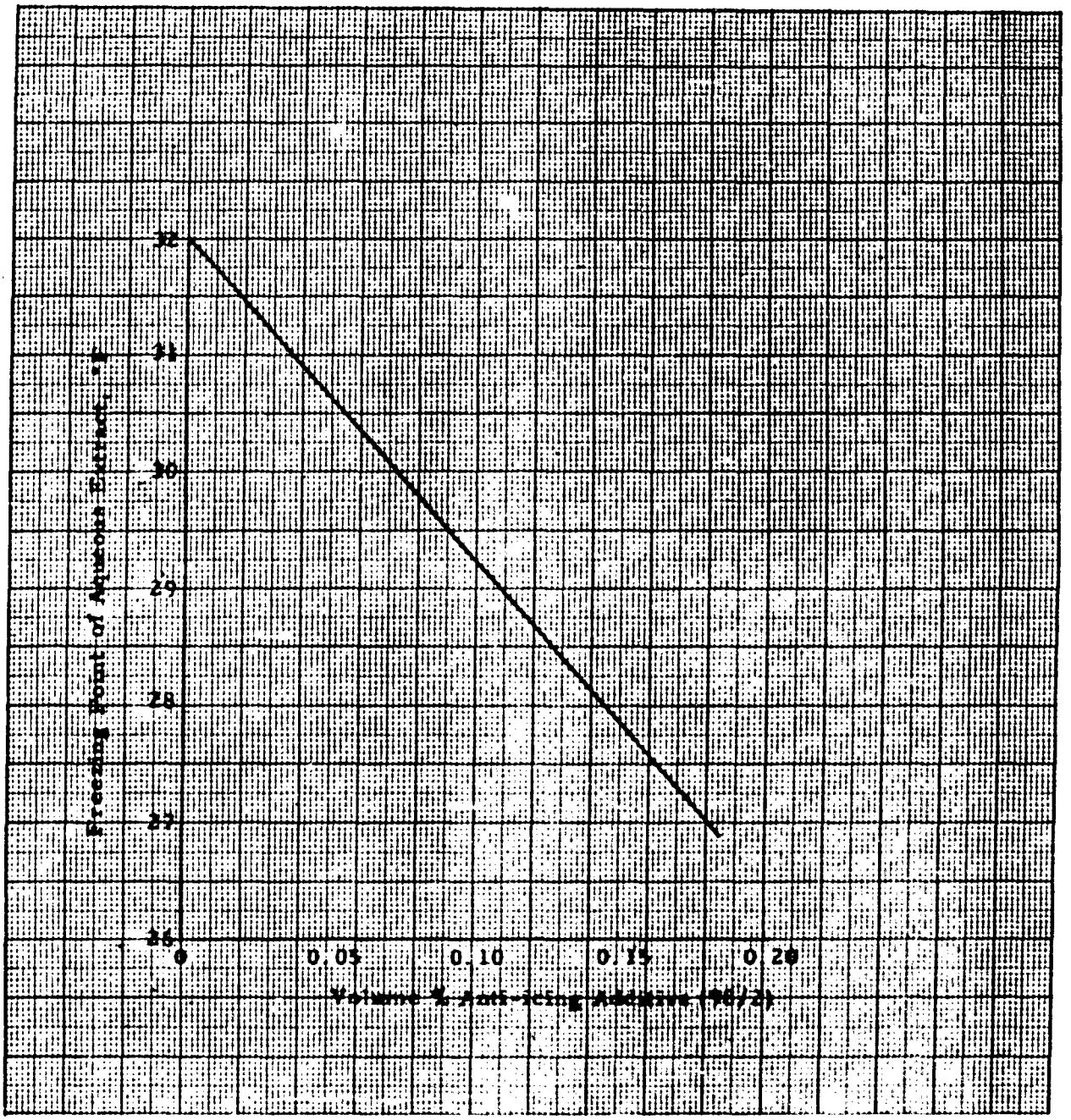


FIGURE 18. CALIBRATION CURVE FOR ANTI-ICING ADDITIVE IN JP-4 FUEL BY THE FREEZING POINT METHOD

F. Other Fuel Tests

1. Particulate Matter - ASTM Appendix X (1960).

2. Water Content - ASTM D1744-60T with KF-3 apparatus.

3. Water Separometer - FTMS-791a Method 3255-T (standard WSI) or Method 3256 (modified WSIM)

G. Microbiological Assays

1. Total Counts

a. Millipore Filter Method

A measured volume of fuel or water bottoms was filtered through a sterile Type HA 0.45-micron filter, which was then transferred to an absorbent pad saturated with nutrient broth (BBL) enriched with dehydrated yeast extract (BBL) to a concentration of 0.5%. Colony counts were made after 3 and 7-11 days' incubation at room temperature. This method usually gave somewhat lower counts than the agar pour-plate method. Hence, the use of the Millipore method was usually restricted to fuel samples, which could not be run by the pour-plate method.

b. Agar Pour-Plate Method

A 1-ml sample, either undiluted or from a serial dilution, was placed in a sterile Petri dish, and 15 ml of melted enriched nutrient agar (at 45°C) was added. The dish was immediately rotated to mix the sample and then left undisturbed to harden. The enriched nutrient agar consisted of nutrient broth with 0.5% yeast extract and 1.5% agar. The plates were incubated at room temperature, since comparative tests had indicated that better growth was obtained at room temperature than at 35°C. Colony counts were made at 24 and 48 hours, then the plates were incubated and examined for fungus growth after 7 days.

The agar pour-plate method was used primarily on the water bottoms and interface samples from Bergstrom and Carswell. The interface samples usually required the addition of Tween 80 to disperse the sample in the diluent. The agar pour-plate method has two disadvantages: (a) It cannot be used on fuel samples, and (b) there is some danger of killing heat-sensitive microorganisms when the plates are poured.

c. Agar Spread-Plate Method

The spread-plate method, which has found wide acceptance in field fuel contamination work, was applied to both fuel and water samples in the SwRI experimental program.

Immediately after sampling a drum or tank, 0.1 ml of fuel sample (undiluted) and 0.1 ml of water bottoms and/or interface sample (undiluted and in tenfold serial dilutions up to 1/10,000) were spread on solid Trypticase Soy medium (TSA) with a sterile glass rod. The plates were incubated at 37°C, and counts were made after 24 and 48 hours. The TSA medium (BBL) consisted of:

Trypticase	15 g
Phytone	5 g
NaCl	5 g
Agar	15 g
Distilled water	1000 ml
pH	7.3

The diluent for the water samples consisted of nutrient broth:

Bacto-Beef extract	3 g
Bacto-Peptone	5 g
Distilled water	1000 ml

2. Sulfate Reducers

Qualitative tests were made for sulfate reducers by injecting 1.0 ml of water sample into a 9-ml vial of API sulfate broth, incubating at room temperature and 37°C, and observing for black precipitate during a one to three week period.

3. Iron Depositers

In the test for detection of iron depositers, 0.1 ml of the water sample was streaked on solid Waksman-Leathen medium and also injected into liquid Waksman-Leathen medium of the following composition:

$(NH_4)_2SO_4$	0.5 g
$NaNO_3$	0.5 g
K_2HPO_4	0.5 g
$MgSO_4 \cdot 7H_2O$	0.5 g
$CaCl_2$	0.2 g
Ferric ammonium citrate	10.0 g
Agar (in solid medium)	20.0 g
Distilled water	1000.0 ml

The plates and tubes were incubated at room temperature and observed from time to time. Presence of iron-depositing organisms was indicated by red discoloration or iron deposition and growth. Both solid and liquid media were effective in detecting iron-depositing organisms.

4. Gas Formers

The presence of gas-forming bacteria was checked by means of an inverted small test tube inside a larger test tube containing about 10 ml of lactose broth. This assembly, after autoclaving to drive the air out of the small test tube, was inoculated with test sample and incubated at 37° C temperature. The presence of gas formers was indicated by gas bubbles trapped in the inverted tube. The quantity of entrapped gas indicated the relative amount of bacteria present.

5. Coliforms

Coliforms were detected by streaking onto EMB agar the lactose broth infusion in which gas formers were indicated. The presence of coliform organisms was indicated by the appearance of bacterial growth having a metallic sheen. The composition of the EMB agar is:

Bacto-Peptone	10.0 g
Bacto-Lactose	5.0 g
Saccharose, Difco	5.0 g
Dipotassium phosphate	2.0 g
Bacto-Agar	13.5 g
Bacto-Eosin Y	0.4 g
Bacto-Methylene Blue	0.065 g
Distilled water	1000.0 ml

6. Fungi

In the early stages of the program, attempts were made to arrive at a valid quantitative count of the fungi present. Obtaining valid counts is complicated by the fact that fungi may form colonies from either the spores or from portions of the living mycelium. Some attempts were made to break up the mycelia by homogenization, but this was not successful in improving the reproducibility.

Direct counts were attempted by the use of a Howard mold counter, but it was found that the fungi in question exhibited unusual numbers of abnormalities in their growth, so that they could not be counted successfully. Counts were also attempted by the use of pour-plate and Millipore filter

techniques analogous to those used for total counts, but inconsistent results were obtained.

The best results in obtaining fungus counts were obtained by using a Seitz filter pad saturated with melted Sabouraud's dextrose agar, pH 5.6. Dry-sterilized Seitz pads were used to filter a measured volume of fuel or water bottoms, using minimum vacuum to prevent the spores from being carried below the first layer of the pad. The pad was then placed in a Petri dish and saturated with melted Sabouraud's dextrose agar. After 5-10 day incubation at room temperature, the mold colonies were counted. Bacterial growth, when it occurred, did not interfere with the fungus counts, and the bacteria were counted separately. Yeasts or yeastlike microorganisms were relatively abundant in some samples and in some cases were difficult to distinguish from the bacterial colonies.

Although no organized effort was made to isolate or identify the fungus species during this work, certain readily recognizable fungi appeared in many of the Air Force base samples, including Hormodendrum, Cladosporium, Aspergillus flavus, Aspergillus niger, Alternaria, Penicillium, and two types of yeast.

In the latter part of the experimental program, no attempt was made to obtain quantitative counts on the fungi. The presence or absence of fungi was determined by streaking on slants or plates of Sabouraud's dextrose or maltose agar and also on plates of Rose Bengal medium, which is recommended by SIM*.

The Sabouraud's media have a pH of 5.6, which favors the growth of most fungi, including the yeasts. Since some bacteria will also grow well at this pH, it is necessary to idfferentiate the fungi by their growth characteristics. The composition of Sabouraud's maltose agar is:

Neo-Peptone	10.0 g
Maltose	40.0 g
Agar	15.0 g
Distilled water to	1000.0 ml

Sabouraud's dextrose agar is the same formulation with dextrose substituted for maltose.

The composition of Rose Bengal-Streptomycin agar is:

Dextrose	10.0 g
Peptone	2.0 g

*Society for Industrial Microbiology, "Proposed Procedures for Microbiological Examination of Fuels," SIM Special Publication No. 1, July 1963.

K_2HPO_4	0.5 g
$MgSO_4 \cdot 7H_2O$	0.5 g
Agar	15.0 g
Distilled water	1000.0 ml
Rose Bengal	50.0 mg
Streptomycin	8.0 ml of 1% aqueous solution

Either of these media can be used for either fuel, interface, or water samples. Fuel samples are allowed to trickle over the surface of the medium, slant, and then left for the fuel to evaporate. Water samples are simply streaked on the surface; sometimes, if the medium is dry, it is desirable to break the surface to embed the fungus filaments or spores. Interface samples must be dispersed in a suitable diluent before streaking.

Incubation is accomplished at room temperature for three to six days.

The presence or absence of fungi can be determined readily by examining the gross appearance of the plates or slants. Many can be identified by examining their growth rate, appearance, and color. If more specific identification is required, a portion may be mounted on a slide and examined microscopically. Identification in this manner is accomplished from the morphology and structure of the fruiting bodies.

If species identification is to be made, the fungus is transplanted and cultured on Czapek's medium, since most of the descriptions relating to airborne fungi refer to cultures on Czapek's medium.

APPENDIX B

TECHNICAL ORDER

JET FUEL QUALITY CONTROL AT AIR FORCE BASE LEVEL

T.O. 42B-1-

TECHNICAL MANUAL

JET FUEL QUALITY CONTROL AT AIR FORCE BASE LEVEL

PRELIMINARY DRAFT - FOR INFORMATION ONLY

8 APRIL 1964

INSERT LATEST CHANGED PAGES. DESTROY SUPERSEDED PAGES.

LIST OF EFFECTIVE PAGES

NOTE: The portion of the text affected by the changes is indicated by a vertical line in the outer margins of the page.

TOTAL NUMBER OF PAGES IN THIS PUBLICATION IS 22 CONSISTING OF THE FOLLOWING:

Page No.	Issue
Title	Original
A	Original
i	Original
1-1	Original
1-2, Blank	Original
2-1 thru 2-2	Original
3-1 thru 3-2	Original
4-1 thru 4-2	Original
5-1	Original
5-2, Blank	Original
6-1 thru 6-2	Original
7-1	Original
7-2, Blank	Original
8-1	Original
8-2, Blank	Original
9-1 thru 9-5	Original
9-6, Blank	Original

*The asterisk indicates pages changed, added, or deleted by the current change.

ADDITIONAL COPIES OF THIS PUBLICATION MAY BE OBTAINED AS FOLLOWS:

USAF ACTIVITIES. - In accordance with T.O. 00-5-2. USAF

NAVY ACTIVITIES. - Submit request to nearest supply point listed below, using form NavAer 140; NASD, Philadelphia, Pa.; NAS, Alameda, Calif.; NAS, Jacksonville, Fla.; NAS, Norfolk, Va.; NAS, San Diego, Calif.; NAS, Seattle, Wash.; ASD, NSC, Guam.

For listing of available material and details of distribution see Naval Aeronautics Publications Index NavAer 00-500.

TABLE OF CONTENTS

SECTION I

INTRODUCTION - GENERAL

1-1. PURPOSE.

1-2. The purpose of this publication is to establish criteria and define recommended practices for quality control of jet fuels at the Air Force base level, in order to assure that fuel quality is maintained at a high level and contamination is minimized throughout the base fuel handling system. It is also intended to establish definite schedule requirements for sampling and analysis of jet fuels.

1-3. SCOPE.

1-4. This publication concerns the bulk handling of jet fuels from the time of delivery to the base through delivery to the aircraft. Handling of jet fuels in drums or other containers is not covered in this publication.

1-5. The criteria and recommended practices given in this publication are intended to apply primarily to JP-4 fuel purchased under Specification MIL-J-5624. Most of the criteria and recommended practices are also applicable to JP-6 fuel (MIL-J-25656) and thermally stable fuel (MIL-F-25524). However, since the JP-6 and thermally stable fuels require special handling and almost surgical cleanliness to ensure maintenance of product quality, the criteria and practices outlined herein should not be regarded as sufficient for handling these fuels.

1-6. Although this publication deals with jet fuels, most of the criteria and recommended practices given herein are also applicable to reciprocating engine fuels (MIL-G-5572).

1-7. This publication deals with daily quality control procedures at the base level. Sampling and analysis of fuels from crashed aircraft or other emergency sampling are not covered in this publication.

1-8. ORGANIZATION AND RESPONSIBILITIES.

1-9. Primary responsibility for fuel quality control at the base level is placed with the Base Fuels Supply Officer or Base Petroleum Supply Officer, with the assistance of the Base Fuels NCOIC or other designated assistant. The Base Fuels Supply Officer will develop directives on fuel handling and quality control and will see that these directives are implemented.

1-10. Primary responsibility for implementation of directives on fuel quality control and on fuel handling in relation to quality control is placed with the Base Fuels Quality Control Inspector, who is in turn responsible to the Base Fuels Supply Officer. The Base Fuels Quality Control Inspector and his assistants will be cleared for access to all aircraft parking areas. At bases at which a base fuels laboratory has been established, the operation of the laboratory will be under the direction of the Base Fuels Quality Control Inspector.

1-11. Assistance in quality or contamination problems may be provided on request by AFSC and AFLC organizations as described in T.O. 42B-1-1.

1-12. The Base Fuels Supply Officer will be responsible for establishing close liaison with the following groups in all activities related to fuel handling:

Base Civil Engineer - maintenance of fixed fuel handling facilities and equipment

Base vehicle maintenance group - maintenance of mobile fuel handling facilities and equipment

Base aircraft maintenance organizations - refueling and defueling operations and aircraft tank draining

The Base Fuels Quality Control Inspector will be responsible for maintaining close day-to-day liaison with these groups at the operating level in all matters pertaining to the maintenance of fuel quality.

SECTION II

FUEL RECEIPTS

2-1. GENERAL.

2-2. This section outlines the criteria and practices to be followed in receiving fuel into the base bulk fuel storage system, insofar as they relate to fuel quality assurance. These practices are intended to assure that only relatively clean fuel with minimum amounts of water is admitted to the base fuel system.

2-3. TANK CARS AND TANK TRUCKS.

2-4. A one-quart sample will be taken from each incoming tank car or tank truck by dipping through the top hatch. In the case of compartmented tanks, a sample will be dipped from each compartment. These samples will be examined visually for visible solids and free or entrained water. In addition, at least one sample from each tank car or tank truck will be checked for conformance to proper grade of fuel by determining the specific or API gravity of the sample and by examination of color and odor.

2-5. In the event of improper grade or excessive amounts of solids and/or water contamination, the Base Fuels Officer will be notified immediately. The Air Force Quality Assurance Representative will be contacted promptly when quality or grade are in question. Unloading of the tank car or tank truck will be delayed to permit additional settling time if the fuel is contaminated. Samples of questionable quality will be tagged and retained. The decision whether to unload the tank car or tank truck, whether to require settling time and removal of contaminants through the drain line, or whether to reject the shipment will be the responsibility of the Base Fuels Officer after consultation with the Air Force Quality Assurance Representative.

2-6. At least one incoming tank car and/or tank truck per day, and preferably one from each carrier, will be sampled by top dipping for analysis at the base laboratory. In the case of compartmented tanks, the compartment to be sampled will be chosen at random.

2-7. Each compartment will be water-gaged by means of a gaging stick or tape and water-finding paste prior to unloading. In the event that more than a trace of water is found, attempts will be made to remove the water either by draining or by the use of a thief-type pump. Water thus removed will not be discharged to the sewer system, as it will always contain some fuel. Disposal will be in accordance with local fire regulations.

2-8. In the case of tank trucks, the quality of the bottom material may be checked by taking a small amount of drain material from the manifold or other bottom drain. In the event that this is clean fuel with only minor amounts of free water and solids, the tank need not be gaged for water.

2-9. The 30- or 40-mesh strainers in the unloading couplings will be inspected and cleaned in accordance with T.O. 37A-1-101 prior to connecting up to a tank car or tank truck. The 80-mesh strainers in the unloading lines will be inspected and cleaned at least weekly, or more often if they are found to be accumulating large amounts of solid material.

2-10. BARGES AND TANKERS.

2-11. Bulk shipments in barges or tankers will be allowed to settle undisturbed for a minimum of three hours before sampling and/or unloading operations are commenced.

2-12. A one-quart all-levels sample will be drawn from each compartment for visual examination and determination of specific or API gravity.

2-13. All cases of heavy contamination or suspected wrong grade will be reported immediately to the Base Fuels Officer and the Air Force Quality Assurance Representative. Suspect samples will be tagged and retained. The decision whether to unload the barge or tanker, whether to require additional settling time and removal of contaminants, or whether to reject the shipment will be the responsibility of the Base Fuels Officer after consultation with the Air Force Quality Assurance Representative.

2-14. At least one sample from each incoming barge or tanker will be submitted to the base laboratory for analysis.

2-15. Each compartment will be gaged for water prior to unloading. In the event that more than a trace of water is found, attempts will be made to remove the water by pumping. The disposal of such water will be in accordance with local fire regulations.

2-16. All strainers and filters in unloading lines will be inspected after each receipt and cleaned if necessary.

2-17. Shore unloading lines will be kept full of fuel and will not be cleared with either sea water or fresh water.

2-18. PIPELINE RECEIPTS.

2-19. The bulk storage tank or tanks used for receipt of pipeline fuel will be gaged for fuel and water levels prior to the receipt.

2-20. Samples will be drawn from the incoming pipeline intermittently during the receipt to assure conformance with grade (gravity, color, and odor) and a reasonably low contamination level as determined by visual examination. A minimum of three samples is required: at the beginning, in the middle, and at the end of each receipt. A minimum of one sample from each receipt, preferably the middle sample, will be submitted to the base laboratory for analysis.

2-21. All cases of suspected contamination or wrong grade will be reported at once to the Base Fuels Officer and to the Air Force Quality Assurance Representative, who will take action on disposition of the fuel.

2-22. All strainers and filters in incoming pipelines will be inspected after each receipt and cleaned if necessary.

2-23. PUMPING RATES INTO BULK STORAGE TANKS.

2-24. At the start of each receipt or series of receipts by any method into a near-empty bulk storage tank, the flow

rate will be reduced to approximately 20-25% of full rated flow until the fuel level in the tank is three to four feet above the fill line. Thereafter, maximum flow will be resumed.

2-25. SETTLING OF FUEL AFTER RECEIPT.

2-26. After each receipt or series of receipts by any method into a single bulk storage tank, the tank contents will be allowed to settle undisturbed for at least one hour prior to gaging and at least four hours prior to issue of fuel to trucks or operating storage. A sample will be taken from near the level of the bulk storage tank suction line; if this sample contains visible suspended solids or free or entrained water, additional settling time will be provided.

SECTION III

BULK STORAGE

3-1. GENERAL.

3-2. This section outlines the criteria and recommended practices for the installation, maintenance, and operation of bulk fuel storage systems, insofar as they relate to fuel quality assurance. These criteria and practices are intended to ensure that only clean, dry fuel is delivered from bulk storage systems to hydrant systems and refueling vehicles. This section relates primarily to vertical aboveground bulk storage tanks, but the information is also applicable in part to underground bulk storage tanks.

3-3. DYKES AND SURFACE DRAINAGE.

3-4. As specified in AFM 85-16, earthen dykes for aboveground tanks require a capacity equal to the tank contents plus a 12-inch freeboard. Drainage of surface water from the dyke area will be provided by means of a ditch and drain line, at least 6-inch, with a gate valve that is normally locked in closed position. Water will be drained from the dyked area in all periods of heavy rainfall or thawing.

3-5. FLOATING-ROOF TANKS.

3-6. Floating-roof tanks, which are the most widely used type for JP-4 bulk storage, depend on a sliding seal between the roof and the tank wall to minimize product evaporation losses and the access of rainwater or melting snow. These seals are of widely varying design, but most of the older types depend on a metal-to-metal sliding seal. Experience has shown that major amounts of water will pass through such seals during periods of heavy rainfall. It is recommended that newer, more positive types of seals should be installed in all new construction and whenever feasible during major maintenance or repair of older installations. Various types of floating-roof seals are described in AFM 85-16.

3-7. If absolutely necessary, calcium chloride may be applied to floating-roof seals to thaw them out. However, the use of calcium chloride causes undesirable contamination of the tank contents and should not be resorted to except in emergency.

3-8. The roof drains on floating-roof tanks are of three types: open drains, siphon drains, and closed pipe drains. The closed pipe drains are the most desirable from the standpoint of minimizing the access of water to the tank interior, and most floating-roof tanks on Air Force bases have been so equipped. The installation of closed pipe drains is mandatory for existing tanks whenever they are opened for inspection. Closed pipe drains consist of a flexible hose or jointed pipe connecting the center roof drain through the interior of the tank to a foot valve located at the bottom of the tank wall. The foot valve will be kept normally closed (except when actually draining water from the roof), in order to safeguard against loss of fuel in the event of a leaky or ruptured line. However, it is important to note that the foot valve must be opened promptly during periods of heavy precipitation, in order to prevent possible damage to the roof.

3-9. During subfreezing weather, the roof drains will be kept closed, drained, and the top entry plugged, except when actually draining water. An alternative method for locations where the subfreezing weather is of short duration is to add ethylene glycol to the roof drain to prevent freezeup, thus eliminating the need for the top plug.

3-10. In the event that fuel appears in any quantity in the roof drain line, this is an indication that the line is leaking, and prompt action will be taken to take the tank out of service for major repairs.

3-11. TANK INSPECTION AND CLEANING.

3-12. All bulk fuel storage tanks will be opened for entry and inspection at least every three years. In addition, yearly inspections without entry are mandatory. The appearance of more than one-half inch (1/2") of sludge on the bottom of the tank will be cause for cleaning the tank. Regardless of the condition of the tank, a three-year cleaning schedule is considered desirable. During such inspection and cleaning, any necessary maintenance can be performed, and a check can be made of the bottom drainage characteristics, to permit the installation of suitable low-point sump drains.

3-13. WATER GAGING AND REMOVAL.

3-14. Bulk storage tanks will be gaged for water daily, and the water should then be drained down to the lowest practicable level, without losing excessive amounts of fuel. Gaging and water draining should also be accomplished after each fuel receipt or series of receipts (at least one hour after completing receipt) and within one hour after heavy precipitation. The appearance of excessive water in the tank bottom after each rainfall is an indication either that (a) the roof seal is very ineffective, (b) the roof drain is not the proper type, or (c) the roof drain line is leaking badly within the tank. This last condition may also be evidenced by the appearance of fuel in the roof drain line.

3-15. Many existing bulk storage tanks cannot be drained of water completely because of irregular bottom configuration and the absence of any positive low-point sump. Whenever a tank is opened for entry and inspection, it is mandatory that a survey be made of the bottom drainage configuration and that a suitable low-point sump or sumps be installed. These sumps may be square or round, with a minimum area of 320 square inches, and a minimum depth of 8 inches. The water drain line in each sump should be extended to within 2 inches of the bottom of the sump. Depending on the tank bottom configuration, these sumps may be placed in the center of the tank, at the edge, or at any point that is demonstrated to be a low point. If necessary, several sumps and drain lines will be installed to provide adequate drainage of the bottom. In addition to the installation of the sumps, consideration should be given to modification of the bottom configuration to permit complete drainage.

3-16. All new tank installations will be made with positively

sloped bottoms and a drainage sump or sumps at the low points.

3-17. Tanks that test consistently water-free are not normal. In such instances, it is probable that the water is being drawn off into the fuel suction line as fast as it accumulates, or that the gaging point is at a high point in the tank bottom. Either of these conditions should be identified and corrected whenever the tank is opened for entry and inspection.

3-18. FILL AND SUCTION LINE CONFIGURATIONS.

3-19. Existing bulk storage tanks have a wide variety of fill and suction line configurations. These are commonly 6" or 8" lines and may extend straight in horizontally without any baffle or deflector. It is recommended that the fill line should be equipped with some type of deflector to direct the flow upward and thus avoid any stirring up of the tank bottoms. It is also recommended that the suction line should also be equipped so as to avoid drawing in the tank bottoms. One configuration that has been used rather widely for both fill and suction lines is simply an angle cut on the end of the pipe, so that the fuel is directed upward in the fill line and drawn from above in the suction line. It is also recommended that the suction line should clear the bottom of the tank by a minimum of 12 inches. This is not the case in most existing tanks and may not be feasible as a modification in many cases. If such a clearance is maintained for the suction line, it will be necessary to provide another suction line at a lower level for use in tank pump-out operations. An alternative type of suction line is a floating suction attached to the floating roof or independently floating. Floating suctions are considered to be most desirable in minimizing the chance of drawing tank-bottom material into the fuel during transfers.

3-20. FUEL SETTLING PERIODS.

3-21. After receipt of fuel in a bulk storage tank, a four-hour settling period is mandatory prior to dispensing fuel to operating storage or to refueling vehicles. Longer settling periods are desirable; if possible, one hour's settling time should be provided for each foot of fuel depth. If it is found not feasible to observe even the four-hour minimum at all times, this is an indication that the bulk storage capacity is inadequate or that the fuel receiving and transfer operations are being improperly scheduled.

3-22. FILTER-SEPARATOR FACILITIES.

3-23. A filter-separator or filter-separators are required in the bulk storage area if this area includes a truck fill stand for refueling vehicles.

3-24. It is recommended that filter-separators should be installed in the transfer line from bulk storage to operating storage. Such installations are not common at present. In view of the large volumes of fuel issued to operating storage at many bases, a bank of filter-separators would be required to avoid frequent element changes.

3-25. SAMPLING AND ANALYSIS.

3-26. Monthly samples are required from each bulk storage tank for submittal to the base laboratory for analysis. These are to be taken as all-levels samples.

Note

Yearly samples are required for submittal to the Area Laboratory for complete inspection tests.

3-27. Daily samples from a single bulk storage tank (all-level or transfer line) are required for base laboratory use in determining the water saturation value by the Karl Fischer method. The tank should be selected to represent the fuel to be used in aircraft servicing on the following day. In the event that a single tank is used for several consecutive days as the sole source of fuel issued, the daily requirement for saturation samples is waived, and the saturation value need be re-established only when changing the tank used for issue.

3-28. A transfer line sample will be taken under full-flow conditions during each issue of fuel to operating storage or to refueling vehicles. This sample will be examined visually for the presence of excessive amounts of solid contaminants and free or entrained water. Any questionable samples will be submitted to the base fuels laboratory for analysis, and corrective action will be taken if contaminated fuel is being issued.

3-29. If a water bottom exists in a given tank, a sample of this water will be taken monthly for sulfides analysis. This sample may be taken through the water drain, after flushing the drain line thoroughly. If this is not feasible, the sample will be taken through the gaging hatch, attempting to collect the water sample within an inch of the tank bottom.

SECTION IV

OPERATING STORAGE AND HYDRANT SYSTEMS

4-1. GENERAL.

4-2. This section outlines the criteria and recommended practices for the installation, maintenance, and operation of operating storage systems, insofar as they relate to fuel quality assurance. These criteria and practices are intended to ensure that only clean dry fuel is delivered from operating storage systems to hydrants and refueling vehicles. This section relates primarily to underground horizontal operating storage tanks, but is also applicable in part to underground bulk storage tanks.

4-3. TANK INSTALLATION.

4-4. Most of the existing underground operating storage tanks were originally installed level. Since underground tanks will shift appreciably during several years of use, it is usually not known whether one end or the other is the high end. The installation of gaging hatches at both ends of each tank is strongly recommended, in order to provide a positive means of water removal. In the case of new installations, the tanks should be installed with at least a 4-inch pitch from one end to the other, and gaging hatches should be provided at each end.

4-5. When existing tanks are opened for entry and inspection, the true low point of each tank should be determined. If feasible, a positive low-point sump should be installed with a separate hatch for water removal.

4-6. The gaging hatches on existing tanks are normally equipped with a slotted pipe extending to the bottom of the tank. It is recommended that these pipes should be removed in order to facilitate water pumpout and also as an aid in obtaining representative fuel samples from the tanks. The use of open gaging hatches will require the use of gaging tape rather than a gage stick when gaging the fuel and water levels.

4-7. The manhole access covers will not be buried. If these covers are below grade level, pits will be provided that are either water-tight or are furnished with adequate drain or pumpout facilities. Alternatively, the manways may be extended to above grade and provided with watertight covers.

4-8. TANK INSPECTION AND CLEANING.

4-9. All underground operating storage tanks will be opened for entry and inspection at least every three years. In addition, yearly inspections without entry are mandatory. The appearance of more than one-half inch (1/2") of sludge on the bottom of the tank will be cause for cleaning of the tank. Regardless of the condition of the tank, a three-year cleaning schedule is considered desirable. During such inspection and cleaning, any necessary maintenance can be performed, and a check can be made of the bottom drainage characteristics, to permit the installation of suitable pumpout hatches and/or sumps.

4-10. WATER GAGING AND REMOVAL.

4-11. Operating storage tanks will be gaged for water daily, and any detectable water should be removed by pumping to the lowest possible level. The water gage level must be held below one-quarter inch (1/4") and preferably below one-eighth inch (1/8").

4-12. FUEL SETTLING PERIODS.

4-13. After receipt of fuel in an operating storage tank, a three-hour settling period is mandatory prior to dispensing fuel to aircraft or to refueling vehicles. Longer settling times are desirable; if possible, one hour's settling time should be provided for each foot of fuel depth. If it is not found feasible to observe even the three-hour minimum at all times, this is an indication that the operating storage capacity is inadequate or that the fuel receipt and issue operations are being improperly scheduled.

4-14. FILTER-SEPARATOR FACILITIES.

4-15. Each operating storage tank is normally equipped with a fixed filter-separator of a capacity matched to the pump (either 300 or 600 gpm). These filter-separators are used in issuing fuel either to aircraft or to refueling vehicles, if the particular operating storage area is provided with a truck fill stand.

4-16. DEFUEL TANKS.

4-17. Older operating storage and hydrant systems are equipped with a separate tank designated to receive defuel, either from hydrant or truck. Newer systems have no designated defuel tank, but it is common practice to reserve one tank per pumphouse for receiving defuel; this tank may be rotated periodically.

4-18. Whenever a tank receives defuel through a hydrant system, the tank contents must be checked by visual examination of an all-levels sample prior to reservicing this fuel to aircraft or transferring to another tank. In the event of suspected contamination, the sample will be sent to the base fuels laboratory for analysis, and the contents of the tank will be held pending the results of analysis. Successive samples will be withdrawn from the tank in such cases, to determine whether the contaminants have settled out satisfactorily.

4-19. HYDRANT PURGING AND FLUSHING.

4-20. Hydrant systems should be equipped with drains at all low points in the piping, so that accumulated water and solid contaminants can be purged weekly by opening the drains while the system is under operating pressure.

4-21. Hydrant flushing is to be performed to remove contaminants that cannot be removed by purging. Flushing will be accomplished under the following circumstances:

a. The system has been idle for 30 calendar days.

b. The system is to be converted to dispense another grade of fuel.

c. The system is not and has not been used previously

for aircraft servicing.

d. Major maintenance has been performed (any maintainance or modification that could have resulted in entry of foreign material to the system). This includes changes of elements in filter-separators.

4-22. Hydrant flushing consists of pumping fuel through the system at maximum rated flow for a period of at least 20 minutes, continuing until visual examination shows that the recirculated fuel is clean.

4-23. SAMPLING AND ANALYSIS.

4-24. Sampling connections will be provided in the issue line from each operating tank, before and after the filter-separator. Samples will be drawn from each of these connections during each refueling operation or other issue, while pumping at full rated flow, and examined visually for the presence of free or entrained water and solid contaminants. All samples of questionable quality will be retained and properly tagged for examination by the base fuels laboratory.

4-25. At least once a week for each operating storage tank, the two samples drawn before and after the filter-separator during an issue operation will be submitted to the base fuels laboratory for analysis.

4-26. At least once a week for each operating storage tank, an all-levels sample will be withdrawn for visual examination and analysis. This sample will preferably be taken just prior to an issue, after a normal settling period of three hours minimum.

4-27. A tank sample will be withdrawn after each hydrant defueling operation, for visual examination, as specified in paragraph 4-18.

4-28. Samples will be taken periodically for visual examination during each hydrant flushing operation, as specified in paragraphs 4-21 and 4-22.

4-29. Hydrant refueling samples (at the aircraft) will be taken as specified in section VII.

SECTION V

REFUELING VEHICLES

5-1. GENERAL.

5-2. This section includes criteria and recommended practices for the operation and maintenance of refueling vehicles insofar as they relate to fuel quality assurance. Criteria applicable to vehicle-mounted filter-separators are given in section VI.

5-3. LINE STRAINERS.

5-4. All line strainers on refueling vehicles will be inspected and cleaned at least weekly.

5-5. WATER REMOVAL.

5-6. Most refueling vehicles are equipped with a water segregator mounted on the bottom of the tank. In addition, certain units incorporate a water-lock valve in the pump suction.

5-7. Segregator sumps and/or other low-point drains will be opened for water removal after the vehicle has received fuel, with a minimum settling period of at least 20 minutes. A sufficient amount of material will be drawn off to ensure that essentially all of the water has been removed.

5-8. On some vehicles, the water drain valve does not have a positive-closing arrangement. Such vehicles should be equipped with an emergency shut-off valve (normally left open) so that regular water draining can be accomplished without the danger of fuel spills.

5-9. In the event that a vehicle tank remains full of fuel for more than one hour, the segregator sump or other low-point drain will be rechecked for the presence of water prior to use of the vehicle in aircraft servicing.

5-10. In the event that excessive amounts of water or solid contaminants are encountered in checking the drains, the vehicle will be withdrawn from service until the cause of the contamination can be determined.

5-11. In cold-weather operations, fuel servicing vehicles will be parked outdoors or in unheated sheds in order to minimize ice or water formation. Under extreme cold-weather conditions, fuel should be "cold-soaked" at least 16 hours in the refueler tanks to facilitate the separation of dissolved water.

5-12. Freezing of tank and segregator drains has become much less of a problem since the introduction of the use of anti-icing additive in the fuel. However, if freezeups occur, either because of extremely cold weather or inadequate content of anti-icing additive, the drains should be thawed immediately using approved types of heaters.

5-13. INTERIOR TANK COATINGS.

5-14. All steel tanks on refueling vehicles will be interior coated using an approved coating material and procedures as outlined in current issues of MIL-C-4556 and QPL-4556.

5-15. SAMPLING AND ANALYSIS.

5-16. Criteria for sampling and analysis are given in section VII, "Aircraft Fueling and Defueling Operations."

SECTION VI

MICRONIC FILTERS AND FILTER-SEPARATORS

6-1. GENERAL.

6-2. This section outlines the criteria and recommended practices for the maintenance and operation of fixed and mobile filters and filter-separators, insofar as they relate to fuel quality assurance.

6-3. Filter-separators are a required installation in operating storage pumphouses, in lines to truck fill stands, on filter-meter-hose carts in Pritchard hydrant systems, and on refueling vehicles used for jet fuel. In some cases, the fixed filter-separators are "conversion jobs"; i.e., the units were originally installed as the old "hay-pack" type of water separators and were later converted for use as filter-separators. This point is of particular importance in determining the proper criteria for element change, as the correct manufacturer's recommendation is that referring to the conversion kit rather than the original.

6-4. Micronic filters are a required installation in filter-meter pits in Panero hydrant systems and on certain fuel servicing vehicles that have not been converted to filter-separators. However, all refuelers used in jet fuel service must be equipped with filter-separators.

6-5. ELEMENT CHANGE CRITERIA FOR FIXED FILTERS AND FILTER-SEPARATORS.

6-6. All fixed filter-separators will have the elements replaced whenever any one of the following criteria is exceeded:

a. Element service of 18 months.

b. Throughput of 5,000,000 gallons for 600-gpm units, 2,500,000 gallons for 300-gpm units, or proportional amounts for other units.

c. Differential pressure in excess of manufacturer's recommendation or below the normal minimum.

d. Any sharp increase or decrease in differential pressure.

6-7. All fixed micronic filters will have the elements replaced whenever any one of the following criteria is exceeded:

a. Throughput of 2,000,000 gallons (for 600-gpm units).

b. Differential pressure in excess of manufacturer's recommendations or below the normal minimum.

c. Any sharp increase or decrease in differential pressure.

6-8. Throughputs can be determined from meter readings in the case of micronic filters in Panero filter-meter pits. However, it must be noted that the meter readings represent the difference between refuel and defuel, whereas the micronic filter throughput represents refuel only. Therefore, the meter readings are low in terms of actual filter throughput. Accurate accounting would require an independent record of the amount of defuel, which would then be added to the meter reading to obtain the true filter throughput. The error involved in ignoring this factor can be very considerable if defueling operations are extensive.

6-9. In most fixed filter-separator installations, meters are not available to record throughputs. Here the throughputs must be estimated by averaging the total throughput at a given pumphouse or determined accurately by totaling the individual fueling and defueling operations.

6-10. Manufacturer's recommended maximum differential pressures must be based on current information for the elements in use, and should not be based on nameplate data, which may be obsolete or inapplicable.

6-11. All differential pressure measurements must be based on full rated flow. If this is impossible, the manufacturer's recommended maximum pressure must be scaled down in proportion to the flow to arrive at the correct maximum. Minimum differential pressures, if not available from the manufacturer, must be based on experience with newly installed elements. A pressure differential lower than that normally experienced is an indication of a ruptured element or incorrect installation. A sharp increase or decrease in differential pressure is an indication of severe plugging or a ruptured element, respectively; either situation calls for immediate corrective action and replacement of the elements.

6-12. ELEMENT CHANGE CRITERIA FOR MOBILE FILTER-SEPARATORS.

6-13. All mobile filter-separators will have the elements replaced whenever any one of the following criteria is exceeded:

a. Element service of 24 months.

b. Throughput of 5,000,000 gallons for 600-gpm units, 2,500,000 gallons for 300-gpm units, or proportional amounts for other units.

c. Differential pressure in excess of 15 psi or below the normal minimum.

d. Differential pressure sufficient to cause automatic shutdown of filter-separators that are so equipped.

e. Any sharp increase or decrease in differential pressure.

6-14. Throughputs can be determined from meter readings, noting that in some cases the meters will give negative readings during defuel operations.

6-15. All differential pressure measurements must be taken at full rated flow, or else the criteria must be based on proportionately lower pressure drops at lower flow rates. Some mobile filter-separator units carry nameplate data showing maximum and minimum curves of differential pressure vs flow rate. For units for which such

curves are not available, minimum acceptable differential pressures must be based on recommendations from the manufacturer or from experience with newly installed elements. A differential pressure lower than normally experienced is an indication of a ruptured element or incorrect installation. A sharp increase or decrease in differential pressure is an indication of severe plugging or a ruptured element, respectively; either situation calls for immediate corrective action and replacement of the elements.

6-16. REJUVENATION OF USED ELEMENTS.

6-17. When element replacement in either fixed or mobile filter-separators is indicated by any of the criteria given previously, no attempt will be made to prolong the life of the elements. Backwashing or mechanical removal of contaminants from the elements is prohibited except in case of emergency.

6-18. MEASUREMENT OF DIFFERENTIAL PRESSURES.

6-19. For fixed filters and filter-separators, direct-reading differential pressure gages have been installed on most units. Some models of such gages have given extremely poor service and are entirely unreliable; other models have proven very satisfactory. The satisfactory models are well protected internally against over-range pressurizing. All gages should be calibrated at three-month intervals. If the gages installed at a particular base have given poor service and reliability or excessive maintenance problems, higher authority should be contacted in an effort to obtain satisfactory gages.

6-20. Older installations of fixed filters and filter-separators may have individual inlet and outlet pressure gages, or a single gage with valving to read inlet and outlet pressures in turn. These are reasonably satisfactory for reading differential pressures on the order of 15 psig, provided the gages are inspected and calibrated regularly. Such arrangements are not satisfactory for reading differential pressures on the order of 6 psig, which is near the cutoff point for element change on some models of filter-separators. Such units must be equipped with direct-reading differential pressure gages in order for the data to be meaningful.

6-21. The same considerations apply to mobile filter-separators, which utilize all of the types of differential pressure gages mentioned in paragraphs 6-19 and 6-20.

6-22. All differential pressure readings should be taken at full rated flow whenever possible. When this is impossible, the flow rate must be indicated along with the differential pressure reading.

6-23. RESPONSIBILITY FOR DETERMINING NEED FOR ELEMENT REPLACEMENT.

6-24. The base fuel quality control unit will maintain differential pressure records on Form AFTO 50-D for all micronic filters and filter-separators. Actual readings may be taken by fuel servicing or civil engineering personnel, but the responsibility for maintenance of records will rest with the fuel quality control unit. Each reading will indicate the differential pressure and also the flow rate at the time the reading was taken. Supplementary records should be kept to convert the readings to "full-flow" basis in the event that any of the readings are obtained at less than full flow.

6-25. The fuel quality control unit will also be responsible for determining the need for interior inspection and/or element replacement based on differential pressure readings. This unit will maintain up-to-date criteria for maximum and minimum differential pressures on all types of micronic filters and filter-separators on the base.

6-26. The fuel quality control unit will also maintain coordination with civil engineering and vehicle maintenance units to determine the need for element replacement based on time and gallonage criteria.

6-27. WATER REMOVAL.

6-28. Most filter-separators are equipped with automatic water discharge valves to remove the coalesced water that settled out within the case. However, additional shutoff valves in the water discharge lines may be left normally closed. Also, all micronic filters and some filter-separators are not equipped with automatic water discharge valves.

6-29. The water must be drained manually from every filter and filter-separator, preferably after each use, but at least daily.

6-30. SAMPLING AND ANALYSIS.

6-31. Each fixed filter-separator effluent will be sampled at each issue for visual examination (see paragraph 4-24).

6-32. Sampling and analysis of effluents from mobile filter-separators and micronic filters in filter-meter pits are discussed in section VII.

6-33. Whenever the elements are changed in any micronic filter or filter-separator (fixed or mobile), samples of the effluent will be taken during the subsequent flushing operation at full rated flow and examined visually (see paragraphs 4-21 and 4-22).

SECTION VII

AIRCRAFT FUELING AND DEFUELING

7-1. GENERAL.

7-2. This section outlines the criteria and recommended practices for aircraft fueling and defueling operations, insofar as they relate to fuel quality assurance.

7-3. REFUELING OPERATIONS.

7-4. Quality control of refueling is accomplished by full-flow sampling at the aircraft skin. All single-point nozzles must be equipped with sampling connections. Similar connections are not usually available for over-the-wing refueling and must be improvised. One device that may be used in an S-shaped copper or aluminum tube inserted into the stream entering the aircraft tanks.

7-5. A full-flow sample will be taken at the aircraft skin for visual examination during each refueling operation. Refueling will be stopped if these samples show free or entrained water or excessive amounts of solid contaminants. Suspect samples will be submitted for laboratory analysis. The filter system involved (filter-meter pit, hose cart, or refueler) will be removed from service until the cause of the malfunction has been determined and corrected.

7-6. During the first operation of each filter system each day, a full-flow sample will be taken at the aircraft skin for laboratory analysis. The filter systems will be rotated so that each system is checked weekly. However, this requirement is waived in the case of alert aircraft parked over a filter-meter pit when there is no fuel servicing to or from the aircraft during this period.

7-7. Solids contents over 2.0 mg/liter or water contents more than 5 mg/liter over the saturation value will be cause for removal of the particular filter system from service and corrective action. Solids contents over 1.0 mg/liter will be cause for resampling and efforts to determine the cause of the contamination.

7-8. DEFUELING OPERATIONS.

7-9. All defuel must be filtered before it is returned to operating or bulk storage in all cases in which this is possible. Such filtration is not feasible in the case of Panero hydrant defueling, in which the defuel bypasses the micronic filter in the filter-meter pit. In Pritchard hydrant defueling, the fuel passes through the hose cart filter-separator. In truck defueling, the fuel must pass through the vehicle-mounted filter-separator as it is pumped back to operating or bulk storage.

7-10. Whenever an operating storage or defuel tank receives defuel through the hydrant system, the tank contents must be sampled and examined visually before transferring to another tank or reservicing to aircraft. Such samples should be drawn as all-levels samples. In the event of suspected contamination, the sample will be sent to the base fuels laboratory for analysis, and the contents of the tank will be held pending the results of analysis. Successive samples will be withdrawn from the tank in such cases, to determine whether the contaminants have settled out satisfactorily.

7-11. When defuel is received in a fuel servicing vehicle, the vehicle tank contents must be sampled and checked visually. If the fuel is clean and dry, it may be transferred to either operating or bulk storage without any further checks. In the event that the fuel contains free or entrained water or excessive solid contaminants, transfer will not be made until the base fuels laboratory has verified the extent and nature of the contaminants.

7-12. When defuel is found to be so contaminated as to be unfit for service, it will be disposed of in accordance with local fire regulations.

7-13. NOZZLE STRAINERS.

7-14. Nozzle strainers of 100 mesh or finer will be used in all refueling operations and in all single-point defueling operations.

7-15. The nozzle screens will be inspected and cleaned daily in accordance with applicable T.O.'s.

7-16. The nozzle screens in single-point nozzles will also be inspected and cleaned before and after each defueling operation.

SECTION VIII

AIRCRAFT TANK DRAINING

8-1. GENERAL

8-2. This section outlines criteria, responsibilities, and recommended practices for checking aircraft tank drains, insofar as they relate to fuel quality assurance.

8-3. All aircraft fuel tanks are equipped with drains for the removal of water and solid contaminants. These may or may not be true low-point sump drains.

8-4. Checking the aircraft tank drains and the removal of free water and settled solids is the primary responsibility of the aircraft maintenance crew. The responsibility of the fuel quality control unit is confined to witnessing as many of these operations as possible, maintaining records on the amounts of water and solids removed, and obtaining samples for analysis as outlined herein.

8-5. SCHEDULING OF TANK DRAINING.

8-6. Aircraft tank drains must be checked in accordance with the T.O. governing the ground handling of the particular aircraft. The checks are normally performed at least one hour after the aircraft has been refueled, but within eight hours of takeoff. Checks are also scheduled at least one hour after an aircraft has been moved from a heated shelter. Deviations from these one-hour minima should be noted, if possible, in the records maintained by the fuel quality control unit.

8-7. For aircraft on alert status, tank drains are required every 72 hours or as directed by the applicable T.O. The fuel quality control unit does not have any responsibility in such draining operations and will not witness them except on request.

8-8. Aircraft tank drain checks are required whenever the ambient temperature is above 0°F. This requirement is in contradiction to existing aircraft T.O.'s, which specify that checks are required only when the ambient temperature is above 32°F. This latter requirement has been made obsolete by the use of anti-icing additive.

8-9. TANK DRAINING PROCEDURES.

8-10. The required equipment for aircraft tank draining includes a clean half-gallon wide-mouth jar (or bottle and funnel) and the necessary tool or device for opening the drain valve. The representative of the fuel quality control unit should also carry several clean quart bottles to receive any questionable samples for laboratory examination.

8-11. Each tank drain is checked by draining one to two quarts of liquid. If clean fuel with only traces of free water is obtained, the check is complete. If major amounts of free water or solid contaminants are obtained, the check is repeated until relatively clean fuel is obtained.

8-12. SAMPLING AND ANALYSIS

8-13. The material drained from the tanks is normally discarded. When appreciable amounts of free water or solid contaminants are obtained, the appearance and amount of free water will be noted (to the nearest half pint), as well as the appearance and amount of the solid contaminants.

8-14. Samples will be retained for laboratory examination in the event of the appearance of very dark-colored water or excessive amounts of solid contaminants. The samples so taken will include both fuel and water phases, if possible. The solid contaminants will be examined microscopically in an effort to determine their origin. The fuel phase will be analyzed in the base laboratory for anti-icing additive content. The water phase may be submitted to the appropriate laboratory for analysis for anti-icing additive content.

8-15. A fuel sample will be taken once a day from each operating squadron. This will represent clean fuel taken from a tank drain following the removal of excess free water and solid contaminants. These fuel samples will be analyzed for anti-icing additive content. No determinations of water content by the Karl Fisher method are to be made on any tank drain samples. Determinations of solids content in such samples by the Millipore method are to be made only in the event of suspected contamination.

SECTION IX

FUEL SAMPLING AND ANALYSIS

9-1. GENERAL.

9-2. This section provides an outline of the criteria and recommended practices in sampling and analysis of fuels, including a summarized schedule of sampling frequency at all points in the fuel system. These criteria and practices are intended to provide complete guidelines to the day-to-day operations of the base fuel quality control unit.

9-3. Since fuel laboratory facilities are not available at some Air Force bases, it is recognized that the criteria for frequency of analysis as presented herein are not applicable to all bases. At such bases, the visual examination of samples should be supplemented by submittal of all questionable samples to the designated Area Laboratory.

9-4. SCHEDULE OF SAMPLING AND ANALYSIS.

9-5. Frequency of sampling and analysis will be in accordance with the accompanying table 9-1.

9-6. SAMPLING METHODS AND DEVICES.

9-7. Approved sampling methods and devices are listed in T.O. 42B-1-1.

9-8. It is recommended that, whenever possible, samples should be taken directly in the sample container, i.e., without the use of an intermediate thief, beaker, or funnel, which can be sources of extraneous contamination. Whenever such intermediate devices are necessary, they must be cleaned thoroughly before each use and rinsed in the fuel being sampled.

9-9. The use of the "Bacon" type thief sampler (T.O. 42B-1-1, figure 3-2) is not recommended. This device is difficult to clean properly and tends to leak fuel in when lowered to any considerable depth in a tank.

9-10. An alternative sampling device, for drawing samples directly into the sample bottles, consists of a hand vacuum pump, a length of weighted polyethylene or soft aluminum tubing, a catch bottle to prevent drawing fuel into the pump, and rubber stoppers and tubing connections as required. This device is not available commercially. Instructions for making up such a sampler will be furnished on request through the Systems Engineering Group (SEHFL), Research and Technology Division, Wright-Patterson AFB, Ohio. This sampler provides direct draw of sample from any depth into the sample container. The tubing is the only component that requires discard or cleaning before re-use.

9-11. SAMPLE TEMPERATURE RECORDS.

9-12. The sample temperature will be recorded at the time the sample is taken in all cases in which the sample is to be submitted to the laboratory for Karl Fischer water determination. Since it is not always known in advance just which samples are to be submitted, it is good practice to record the temperature on all samples.

9-13. All personnel taking samples will be equipped with a thermometer and pocket carrying case of approved type. These thermometers will be checked for accuracy periodically by the base fuels laboratory.

9-14. Precautions will be taken to ensure that the thermometer and the inside of the carrying case are kept clean. If possible, the thermometer will be rinsed in the fuel being sampled prior to its insertion in the sample bottle. A clean, lint-free rag will be carried by all sampling personnel to wipe the thermometer before and after use.

9-15. The sample temperature will be obtained immediately after the sample is taken, by inserting the thermometer and stirring until the reading becomes steady. This should be done in the shortest possible time, usually a matter of a few seconds. The water content of a sample will change rather rapidly when the bottle is open, so this period must be kept at a minimum.

9-16. SAMPLE CONTAINERS AND SAMPLE HANDLING.

9-17. Approved containers for submittal of samples to Area Laboratories are specified in T.O. 42B-1-1.

9-18. All other samples will be taken in one-quart bottles of the "French Square" type with foil-lined metal or plastic screw caps.

9-19. New bottles and caps as purchased are normally not clean, especially in terms of lint and fibers. All new bottles must be washed in the laboratory with hot water and detergent, rinsed with hot water and then with filtered distilled water, and air or oven dried in an inverted position. All new caps must be rinsed with filtered mineral spirits or filtered fuel before use. The cleaned caps will be placed at once on the clean sample bottles. It is good practice to protect the capped bottles from dust by hooding the necks with aluminum foil or plastic wrap.

9-20. These procedures will provide bottles that are sufficiently clean for use in the sampling and analysis outlined herein. However, it must be recognized that such procedures do not provide true particle-free bottles, which require much more elaborate procedures. Therefore, when microscopic examination is made of solids filtered from samples, it should be recognized that some of the material, particularly fibrous material, may be derived from the sample bottles.

9-21. After the initial cleaning, the sample bottles may be re-used in the field for sampling for visual examination, provided the samples do not show free or entrained water or visible solid contamination. All such contaminated bottles must be rewashed. Such rewashing may follow the original procedure for new bottles (paragraph 9-18) or may consist of rinsing with filtered anhydrous isopropanol and then with filtered petroleum ether, followed by air drying in an inverted position.

9-22. All bottles used for regular submittal of samples to the base laboratory for analysis must be laboratory-washed prior to use.

9-23. Sample bottles will not be opened in the field until ready to take the sample. The caps will not be laid on the ground during sampling. All precautions will be taken to ensure that dust or other extraneous contamination does

Table 9-1. Frequency of Sampling for Quality Control at Base Level

Operation and Sampling Location	Sampling Method	Visual Examination*	Laboratory Analysis**		
			Mil and K-F	AIA	Other
Fuel Receipts					
Tank cars	Top	All compartments	1/day	1/week	-
Tank trucks	Top	All compartments	1/day	1/week	-
Barges	All-levels	All compartments	1/receipt	1/receipt	-
Tankers	All-levels	All compartments	1/receipt	1/receipt	-
Pipeline	Line	3/receipt (min)	1/receipt	1/receipt	-
Bulk storage tanks after receipt or series of receipts	Lower	1/receipt or 1/series	-	-	-
Bulk Storage					
Each tank	All-levels	-	1/month	1/month	-
Each tank, for Area Laboratory	All-levels	-	-	-	1/year
One tank, for saturation value	All-levels or line	-	-	-	1/day***
Transfer line to operating storage	Line	Each issue	-	-	-
Transfer line to truck fill stand, after F/S	Line	Each issue	-	-	-
Each tank, water bottoms, for sulfide test	Drain line	-	-	-	1/month
Operating Storage and Hydrant Systems					
Each fixed filter-separator (before and after)	Line	Each issue	1/week	-	-
Each operating storage tank	All-levels	-	1/week	1/week	-
Defuel tanks	All-levels	Each defuel	-	-	-
Hydrant flushing, after filter-separator	Line	Each operation	-	-	-
Refueling and Defueling					
Each filter system, refueling sample at aircraft skin	Line	Each issue	1/day	1/week	‡
Defuel tanks in hydrant systems			See Above		
Defuel received in vehicles	All-levels	Each defuel	-	-	-
Aircraft Tank Draining					
Material first drained	Catch	Each drain	-	-	-
Clean fuel after draining	Catch	-	-	1/day from each squadron	-

* Samples that are of questionable quality based on visual examination will be submitted for analysis.

** All samples submitted for laboratory analysis will also be examined visually. Code for determinations: Mil - total solids by Millipore method; K-F - total water content by Karl Fischer method; AIA - content of anti-icing additive by titration or colorimetric comparison.

*** Samples for saturation value will be taken daily if the tanks are rotated daily or if fuel is being received daily. The daily requirement for saturation value may be waived if one tank only is used for issue on several successive days. In this event, the saturation value need be re-established only when changing the tank used for issue.

‡ Monthly samples will be taken from each filter system for correlation with Area Laboratory.

not get into the sample bottle. Immediately after the sample is taken, the bottle will be capped tightly and left capped

9-24. Just before drawing a fuel sample, the sample bottle must be rinsed twice in the fuel stream or in fuel from the tank being sampled. This provides additional insurance against bottle contamination and also equilibrates the bottle with the temperature and moisture content of the fuel being sampled.

9-25. Bottles will be filled only to just below the shoulder. This is a safety measure and also makes it easier to obtain representative samples for the laboratory tests.

9-26. Samples will not be exposed to direct sunlight nor to diffuse light any more than strictly necessary. It is recommended that personnel taking samples should be equipped with an insulated, opaque container to prevent rapid temperature changes of the samples and to protect them from sunlight. It has been found that exposure to

light may cause changes in the Millipore solids content of fuel samples.

9-27. When samples are brought to the laboratory for analysis, they will be left outside at ambient temperature, protected from light, until ready for analysis.

9-28. When a sample is brought into the laboratory for analysis, the contents will be agitated vigorously before drawing any material for analysis. The Karl Fischer water determination will be performed first, and the bottle will not be left open for any reason until this determination is completed. If the anti-icing additive determination is to be performed, this will be done next. Finally, the remaining contents of the bottle will be agitated thoroughly, and the Millipore solids determination will be performed.

9-29. VISUAL EXAMINATION.

9-30. Ordinary criteria for clean fuel require that the sample be "clear and bright" and free of visible solid contaminants and of visible free or entrained water. These criteria are discussed in some detail in T.O. 42B-1-1. Such criteria are entirely satisfactory in examining samples of fuel receipts and samples from bulk and operating storage systems. Gross contamination, either by water or solids, is clearly visible, and corrective action can be taken.

9-31. The situation is more critical in relation to refueling samples, where the appearance of visible contamination is cause for shutting down the aircraft refueling operation. Here it is necessary to set up standard viewing conditions.

9-32. It is recommended that each refueling vehicle and each hose cart should be provided with a viewing box for examining refueling samples under standard conditions. This box will consist simply of a wooden or even corrugated board box, approximately 6" X 6" X 6", with a hole cut in the top just large enough to accommodate the one-quart sample bottle. A 1" round port is provided in the center of one side for illumination, and another 1" round viewing port is provided in the center of another side, at 90° to the illumination port. The interior of the box is painted dull black. The top of the bottle is covered with an opaque cloth to cut down on stray illumination.

9-33. For operation at an aircraft refueling operation, illumination may be provided by the vehicle headlight or by another available source of strong and relatively constant illumination. Flashlights are not considered satisfactory.

9-34. Viewing under these conditions will show up large numbers of particles even in "clean" fuels. These can be distinguished from air bubbles by the tendency of the latter to rise. Such viewing will also show up traces of entrained water in the form of a cloud that may be undetectable under ordinary viewing conditions.

9-35. At present there are no standards of fuel cleanliness based on visual examination under these conditions of optimum illumination. However, an experienced operator can readily distinguish between normal clean fuel and contaminated fuel. It is recommended that each base develop standards based on their own experience until such time as general standards can be developed.

9-36. Under ordinary illumination, the presence of more than four or five visible fibrous or metallic particles, or the presence of visible free or entrained water, will be cause for shutting down the refueling operation and withdrawal of the particular filter system from service until the cause of the malfunction has been identified and corrected. Likewise, the presence of excessive solids on the bottom of the bottle, or the presence of a cloud due either to solid particles or water, is cause for shutdown and corrective action.

9-37. MILLIPORE SOLIDS DETERMINATIONS.

9-38. The total content of particulate matter in fuel samples will be determined by Millipore filtration in accordance with T.O. 42B1-1-13. It should be noted particularly that the total sample must be filtered in order to obtain a correct value; therefore, the Millipore solids determination must be performed last, after removal of sample for other determinations.

9-39. Results of the Millipore solids determination will be reported in mg/liter.

9-40. Millipore solids values above 2.0 mg/liter on refueling samples will be cause for immediate withdrawal of the filter system from service and corrective action. Millipore solids values above 1.0 mg/liter on refueling samples will require resampling and efforts to determine the source of the contamination.

9-41. Millipore solids values above 2.0 mg/liter on other samples (fuel receipts, tanks, and lines) will require resampling and efforts to determine the source of the contamination.

9-42. Microscopic examination of the solids will be made in all cases of excessive values, as an aid in determining the source of the contamination.

9-43. Noncombustible solids may be determined as an aid in determining the source of contamination. However, the noncombustible solids values will not be used as criteria for withdrawal of filter systems from service.

9-44. Ordinary laboratory analytical balances are not sufficiently accurate for determining the weight of solids to the nearest 0.1 mg. It is recommended that a microanalytical balance with suitable ionizing source (to eliminate static electricity effects) should be provided. Information on suitable balances may be obtained from the Air Force Aerospace Laboratory, Wright-Patterson AFB, Ohio, Attention MAOQLA.

9-45. ANTI-ICING ADDITIVE (AIA) DETERMINATIONS.

9-46. The anti-icing additive content of fuel samples may be determined either by the dichromate titration method (Federal Test Method Standard 791a, Method 5327.1) or by the dichromate color comparison method (Federal Test Method Standard 791a, Method 5330). The titration method is the more accurate; the color comparison method is simpler and is adequate for use in base quality control. The procedure for the color comparison method is also given in T. O. 42B-1-1.

9-47. The AIA content of fuel receipts should be 0.1%

minimum but may run as low as 0.08%. Values below 0.08% should be brought to the attention of the Air Force Quality Assurance Representative, for corrective action by the fuel supplier.

9-48. The AIA content of fuel from bulk and operating storage tanks should be 0.06% minimum and preferably 0.08% or higher. Lower values indicate the access of excessive quantities of water to these tanks and the need for corrective action.

9-49. The AIA content of refueling samples must not be less than 0.05%. Lower values will require the isolation of the particular storage and filter system until the cause can be identified and corrected.

9-50. KARL FISCHER WATER DETERMINATIONS.

9-51. Determinations of water content will be carried out basically as outlined in T.O. 42B1-1-13.

9-52. It is recommended that the Karl Fischer reagent should be standardized directly against known amounts of water, and that the use of water-methanol mixture as an intermediate standard should be eliminated. It is also recommended that the known amounts of water should be injected with a microliter syringe, thus eliminating the necessity for weighing the syringe. The use of microliter syringes has been found to be more convenient and reliable than actual weighing. The standardization of the Karl Fischer reagent should be performed at least once a day, and preferably twice if samples are being run throughout the day.

9-53. All results of Karl Fischer determinations will be expressed in mg/liter. The existing procedure (T.O. 42B1-1-13) gives results in parts per million by volume, which is equivalent to mg/liter.

9-54. It is required that the sample temperature be determined in the field at the time the sample is taken. This temperature is used in comparing the result of the water determination with the corresponding saturation value.

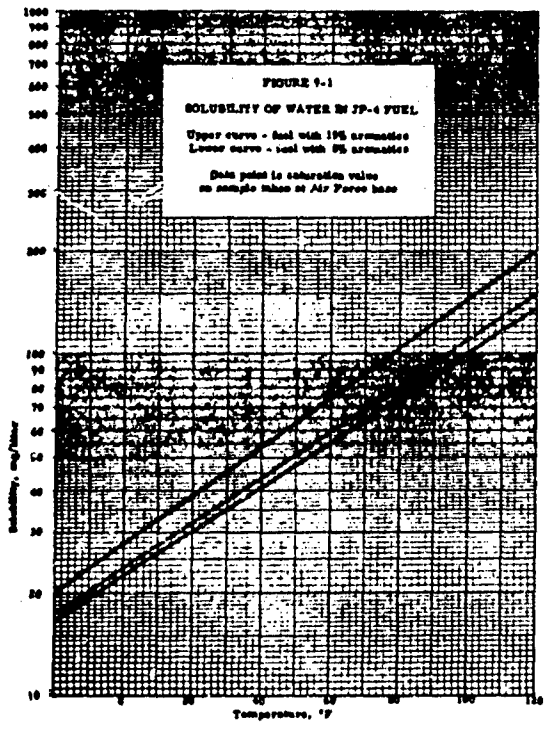
9-55. The sample will be maintained at a temperature not lower than the sampling temperature until ready for analysis. It need not be equilibrated in a water bath.

9-56. Vigorous agitation of the sample is required prior to withdrawal of material for the water determination. This is particularly important in case the sample contains free or entrained water.

9-57. SATURATION VALUES BY THE KARL FISCHER METHOD.

9-58. The existing method of determining the water saturation value of bulk storage fuel (as described in T.O. 42B1-1-13) does not give meaningful results. The procedure outlined in the following paragraphs will be used instead.

9-59. Typical curves of saturation value vs temperature will be established for various fuels, using the procedures outlined in the following paragraphs and equilibrating at various temperatures. These need not represent fuel at a particular base. Such a plot for two fuels is shown in figure 9-1. It will be noted that linear plots are given on semilogarithmic paper. This pair of curves is satisfactory for base use. However, any base may establish saturation curves nearer their typical fuel.



9-60. Each saturation sample will be equilibrated at some constant temperature with 4 ml of water in the bottom of the bottle. This bottle will be left undisturbed for 16 hours. The constant temperature should be chosen to be close to the expected sampling temperatures. A cold-water bath may be satisfactory if the water temperature is reasonably constant. A thermostated bath is more satisfactory.

Note

Saturation samples will be taken daily from bulk storage if the tanks are rotated daily; if one tank is the sole source of fuel issues for several days, the daily requirement is waived.

9-61. After completing the 16 hours equilibration, a fuel sample is withdrawn (without agitation or disturbance) and analyzed for water content as outlined in paragraphs 9-50 through 9-53. This water content is the saturation value at the equilibration temperature.

9-62. A point representing this saturation value and the corresponding equilibration temperature is plotted on

figure 9-1 or similar graph. A line is drawn through this point parallel to the lines for typical fuels. This line represents the saturation line for the day's samples

9-63. The saturation value corresponding to a given fuel sample from the system is determined from this saturation line, using the sampling temperature to read the corresponding saturation value.

9-64. SIGNIFICANCE OF KARL FISCHER WATER DETERMINATIONS.

9-65. Using the outlined procedures, the Karl Fischer determinations give results that can be expressed in mg/liter above or below the saturation value corresponding to the particular sampling temperature.

9-66. In the case of refueling samples, a water content more than 5 mg/liter above the corresponding saturation value indicates equipment malfunction and requires immediate withdrawal of the particular filter system from service for identification and correction of the malfunction.

9-67. In the case of fuel receipts and samples from bulk and operating storage tanks and lines, a water content more than 10 mg/liter above the corresponding saturation value indicates passage of entrained or free water and the need for corrective action.

9-68. RECORDS OF LABORATORY ANALYSES.

9-69. Each sample received at the laboratory will be assigned a number and logged in on a summary form (for example, SAC Form 213, Laboratory Fuel Condition Summation). The results of analyses will also be entered on this form. Records will also be maintained for each laboratory analysis on forms provided (for example, SAC Form 214, Laboratory Analysis Record of Sediment Progress; SAC Form 215, Laboratory Analysis Record - KF-3 Aquameter; SAC Form 217, Laboratory Analysis Record of Fuel Icing Inhibitor).

9-70. In addition, the laboratory will maintain a running log of the results of analyses for each filter system or other sampling location. This log may be in the form of a table or graph and is intended to show a continuous record of the performance of a given piece of equipment and to indicate clearly when corrective maintenance is needed. This log will include the results of all laboratory analyses. In addition, in the case of filters and filter-separators, either fixed or mobile, this log will include the differential pressure readings obtained daily or at each sampling.